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CHEMICAL RECREATIONS.

PART I.

CHEMICAL MANIPULATION.

ANALYSIS BY THE BLOWPIPE.

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A

COMPENDIUM

OF

EXPERIMENTAL CHEMISTRY.

BY

JOHN JOSEPH GRIFFIN,

TRANSLATOR OF ROSE'S MANUAL OF ANALYTICAL CHEMISTRY.

The Eighth Edition.

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PART FIRST,

COMPRISING

CHEMICAL MANIPULATION,

AND

ANALYSIS BY THE BLOWPIPE.

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PREFACE.

NECESSITY, rather than choice, obliges me to issue the present edition of CHEMICAL RECREATIONS in detachments. I intended to have published the whole at once, but the limited time which my commercial avocations permit me to devote to science, prohibits any approach to a speedy execution of the amendments which I had planned upon the preceding edition of this work, and incautiously attempted to effect. A comparison of the present publication with the corresponding portion of the seventh edition of CHEMICAL RECREATIONS, will satisfy the reader that the amendments introduced are to such an extent, and of such a character, as, in fact, to constitute a new work. The alterations which I intend to make upon other portions, though not perhaps so revolutionary as those which I have made upon this portion, are, nevertheless, such as can only be effected by an expenditure of time so considerable, that I find myself under the necessity, either of delaying the publication of the whole work for an indefinite period, or of publishing apart the portion which is now finished, and which comprehends *a complete and important subject*. In this dilemma, I adopt the latter alternative, and publish this essay on MANIPULATION, with an engagement to finish the residue of the work at the earliest opportunity.

I am the more induced to take this course, by the commendations which a number of my chemical friends have been pleased to pass upon some new chemical apparatus, of which, in a species of chemico-commercial experiment, I have superintended the manufacture, with an endeavour so to combine and organise it, as to reduce the expense of apparatus to such a degree as to

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make the introduction of chemical tuition into schools no longer to be dreaded by teachers, as they have hitherto dreaded it, as *a certain source of pecuniary loss.*

An account of my attempts to discover, to collect, or to construct cheap chemical apparatus, and to simplify the performance of analytical processes, is, therefore, here placed before the public, and I will trespass upon the reader's attention with a few explanatory observations. My study has been, in the first place, to develope the nature and objects of the more important processes of the science; in the next place, to consider the means and appliances whereby the chemists of modern times are accustomed to bring out the results of these processes; and finally, to produce such modifications of those experimental means, as, without abating from their utility, should operate to the reduction of the three great evils of high cost, scarcity, and difficulty of management. That the prevalence of these evils has hitherto repressed the extensive diffusion of chemical knowledge, is undeniable. I thought it worth while to determine whether these curbing powers prevailed of necessity, or from accident. My investigations have led me to draw the latter conclusion. I find that the evils referred to can be readily overcome, and I shall show in the following pages, that serviceable chemical apparatus can be made as cheap, as plentiful, and as easy to use, as the instruments which have long been employed in illustrating the usual school-taught sciences of geography, geometry, and astronomy.

It is needless to inform the reader how much trouble and time have been bestowed upon the investigations and experiments which the execution of such a work compelled me to undertake. The accumulation of existing descriptive matter, though that has been gathered from many distant and scattered places, formed but a small part of the necessary labour. The making and trial of innumerable modified forms of apparatus, was a much more arduous task; so also was that of gathering apparatus and materials from France, Prussia, Bohemia, Austria, Saxony, and Sweden, as special purposes rendered necessary. But the superintendence of the manufacture of large quantities of such articles as were proven to be most useful, a manufac-

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ture persevered in under considerable difficulties, for the purpose of resolving the question of *how low the reduction of prices could be carried under a suppositious extension of demand for apparatus*—this was the most troublesome, tedious, and expensive branch of the enquiry.

The results of these researches, however, are the production of many new and cheap instruments, adapted for purposes which formerly required those of an expensive kind, and the contrivance of many new and easy methods of experimenting, applicable to cases which previously were attended by numerous difficulties. By the introduction of stoneware apparatus, and by making such alterations in the form of many vessels as facilitates their adaptation to different purposes, I have at once reduced their price, and lessened the number necessary for general use; while, by the organization of apparatus adapted for the simultaneous performance of processes by large classes of students; by the use of circular filters, test books, improved tube holders, and other contrivances; I have provided the means of SAVING TIME in experimenting, which my experience leads me to consider to be a matter of greater importance than even the reduction in price of the apparatus. The *tendency* of these results will be to facilitate the teaching of elementary chemistry, and consequently to lessen its expense; to facilitate the practice of chemical analysis, and consequently to extend more widely the beneficial applications of Chemistry among all persons whose professions or manufactures render them in any degree dependent upon that science.

The application of the commercial principle of creating a demand for goods, by proffering a cheap supply, has never hitherto been made to chemical apparatus. I flatter myself with the hope that the present attempt will not become remarkable by merely demonstrating that the diffusion of science cannot be promoted by such a means. I rely too strongly upon the justness of the commercial axiom, to anticipate such a result as that. On the contrary, I trust that a popular desire for the acquisition of chemical knowledge will be roused where it is now dormant, and created where it does not exist, by the power which this new apparatus confers of acquiring that know-

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ledge cheaply and readily; and I am induced to hope that the work which embraces the details of my enquiries, coupled with instructions for enabling others to avoid the difficulties which I have encountered, and to reach their object by a shorter cut, or "royal road," will not be considered by practical persons as a useless addition to British chemical literature.

I take this opportunity of acknowledging the obligations which I am under for many hints and articles contained in the following pages, to the undermentioned works:—

Chemische Operationen und Geraethschaften, von J. Jacob Berzelius, 1831.

Die Anwendung des Loethrohrs, von J. Jacob Berzelius, Dritte Auflage, 1837.

Handbuch der analytischen Chemie, von Heinrich Rose, Dritte Auflage, 1833.

Lehrbuch der Chemie, von E. Mitscherlich, 1835.

Die Probirkunst mit dem Loethrohre, von C. F. Plattner, 1835.

Communications from personal friends, and abstracts from works not cited above, are generally quoted as such in the text.

Glasgow, November 30th, 1837.

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PREFACE TO THE SEVENTH EDITION

OF

CHEMICAL RECREATIONS.

A LITTLE book like the present has no claim to a long preface. A few words will explain its plan and tendency.

It exhibits a condensed account of the nature and objects of chemistry, and of the method by which it may be learnt.

It contains a description of the handiest methods of making chemical experiments on a small scale, either to prove what is known, or to determine what is unknown.

It embraces an account of the properties of the elementary bodies, and of the most important compounds originated by their combinations.

It contains a series of experiments, calculated to display the remarkable properties of particular substances, and the general nature of chemical phenomena. These experiments will be found as interesting in performance, as instructive in their results. They are such as can be executed with little cost and without difficulty.

Lastly, the work unfolds the principles of theoretical chemistry, examines the groundwork and superstructure of the prevailing theory of Chemistry, points out its defects and the confusion to which the defects give rise, suggests a remedy, and presents a Nomenclature, a System of Arrangement, and a Theory of Combination, founded upon new principles.

Such is the plan, and such the tendency of this work. It has the fault of taking perhaps too wide a circuit, and of bringing together subjects adapted for students of a different status; but

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I have been induced to adopt this course by a desire that my readers should be taught to *think* as well as to *experiment*, and thus be qualified, at an early part of their study, to discriminate between the true and the false, and acquire the facts of the science without being mystified by its fictions.

The critic who may incline to censoriousness, is reminded that the task I have undertaken is no easy one. To reform the nomenclature of chemistry, is to cleanse the Augean stable, where rubbish has been accumulating for forty years.

Glasgow, June 1, 1834.

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INTRODUCTION.

NATURE OF CHEMISTRY.—Chemistry is the science which makes known to us the properties of the component particles of all natural bodies. I speak not only of those *compound* particles which are the result of organisation, but of the ultimate, indivisible, or *elementary* particles. It treats of the infinitely various *sorts* of substances, and of the exact determination of their differences. It exhibits the means by which the component parts of compound bodies can be separated from one another, or by which the elements of compounds can be made to combine together. In fine, it shows by what contrivances the corpuscles which constitute the world, can be most beneficially applied to the service of man.

OBJECTS OF CHEMISTRY.—The objects of chemistry are inexhaustible. It undertakes the examination of all substances which act upon the senses. It seeks to determine the properties of those substances, the number and proportion of their component particles, the individual nature of those components, and the properties of all other compounds which can be produced by their combination, either in different numbers or in different proportions. There are no bounds to the researches of chemistry; because, at whatever point its operations commence, there is no telling to what they may lead. Indeed, so infinitely varied are its objects, that it is an everlasting source of occupation and amusement; and while, on this account, it receives the attention of the curious philosopher, it claims the notice of all men, from its utility in the arts by which the comforts and existence of civilised life are promoted and supported.

USE OF CHEMISTRY.—The great importance of the science of Chemistry is rendered evident by the following considerations: It is useful in explaining natural phenomena: indeed, in determining the constitution of the atmosphere, in investigating the

changes to which it is subject, the variations of temperature, the laws of winds, dew, rain, hail, and snow, Chemistry is our principal, our only satisfactory guide. These remarkable changes in the face of nature—changes which, because familiar, do not produce any emotion in the mind, though in themselves truly wonderful—are chemical operations on a magnificent scale, and can only be explained by chemical laws.

In man's researches into the nature of the things whence he derives the means of his comfort, his happiness, his luxuries, and even his existence—in examining the various objects which compose the mineral, the vegetable, and the animal kingdoms, Chemistry is essentially requisite for the successful progress of his inquiries.

In considering the application of Chemistry to the improvement of the arts of civilized life, a wide field of contemplation opens to our view. So extensive, indeed, are its influence and importance, that, in most of the arts, many of the processes—in some all that are employed, depend on chemical principles. The bare mention of some of these arts will suggest ample illustrations of its extensive utility.

In the medical art, so great is the service of a knowledge of Chemistry, that its practical acquisition is now universally regarded as an essential branch of a medical education. In the art of extracting metals from their ores, in purifying and combining them with each other, and in forming instruments and metals—whether for useful or ornamental purposes—almost all the processes are purely chemical. The arts of glass and porcelain making, of tanning, soap-making, dyeing, and bleaching, depend entirely upon chemistry; and all the processes in baking, brewing, and distilling, most of the culinary arts, and many other processes in domestic economy, are chemical operations. In short, wherever, in any of the processes of nature or of art, the accumulation or the diminution of heat takes place—wherever a sensible change is to be effected by heat—wherever substances in combination are to be separated—wherever the union of simple substances and the formation of new compounds are to be effected—the operations and their results can only be explained on chemical principles.

From this general view of the extensive applications of chemical science to the arts, those who have not considered the objects which it embraces will be enabled to judge of the importance of this study.

If we consider Chemistry purely as a science, we shall find no subject better calculated to encourage that generous love of truth which confers dignity and superiority on those who successfully pursue it. There is no science which holds out more interesting subjects of research, and none which affords more striking proofs of the wisdom and beneficence of the Creator of the universe. A machine constructed by human art, is admired in proportion to the simplicity of its contrivance, to the extent

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of its usefulness, and to the niceness of its adaptations. But the works of man sink into nothing when brought into comparison with the works of nature. When we examine the former, every step of our progress is obscured with comparative clumsiness and defect: in contemplating the latter, we behold perfection rise on perfection, and more exquisite wonders still meeting our view. It is the merit of Chemistry, that by its aid we are enabled to take a minuter survey of the great system of the universe. And we find, so far as our limited powers can comprehend it, that the whole is nicely balanced and adjusted, and that all its changes tend to the most beneficial purposes. Circumstances which, on a superficial view, were seeming imperfections and defects, a closer inspection points out to be real excellencies. In all the singular and surprising changes which everywhere present themselves, the more closely we observe and examine them, the more do we admire the simple means by which they are accomplished, and the intelligent design and perfect wisdom displayed in the beneficial ends to which they are directed.

To these considerations respecting the usefulness of Chemistry, we may add another, which, at a period when Chemistry is taking its proper place in schools as a branch of general education, is not without its interest. This consideration is, that Chemistry is a subject qualified to train both the *mind* and the *hands* of young people to habits of industry, regularity, and order. It teaches the doctrine that accurate and extensive observation is necessary for the accumulation of facts; that careful and exact comparison is necessary for the reduction of these facts to general statements; that logical precision is necessary in estimating the relative value of various problematical statements on points where positive information is wanting; that, consequently, the chemist must study to become capable of judging according to *presumptive evidence*, and in that manner habituate himself to the formation of sound opinions on all subjects that come under his cognizance.

Again, the necessity of observing the most scrupulous and constant regard to *cleanliness* in experimenting, as being indispensable to success, must gradually induce habits of neatness and cleanliness even in the most slovenly; while the equally unavoidable necessity of carrying on the different steps of an operation in an orderly and cautious manner, must have a corresponding moral influence upon persons of the most careless disposition.

Independently, therefore, of any advantages to be hoped for from the possession of the mere facts of Chemistry, setting entirely out of view the applications, either of the principles or the details of the science to the prospective commercial or scientific pursuits of the young student, there is, in the mental and moral discipline which its study affords, high inducements for making chemistry a stated branch of liberal education.

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METHODS OF CHEMICAL RESEARCH.—It has been demonstrated by the experiments of chemists, that the marvellous diversity of appearance under which bodies are presented to the eye, and the unceasing changes to which they are subject, are occasioned by the mutual reactions of a small number of unchangeable elementary particles. The distinctive properties of these particles, the nature of the phenomena which mark their reactions, the methods of causing them to combine, the properties of the resulting compounds, and the methods of decomposing these compounds,—are, consequently, the objects which the chemical student is called upon to investigate.

There are two methods of proceeding in the acquisition of chemical knowledge; these are called *analysis* and *synthesis*. ANALYSIS means the art of *separating* the constituents of compound bodies,—SYNTHESIS the art of forming compounds, by the *putting together*, or effecting the *combination*, of their component particles. Both analysis and synthesis are practically effected by the performing of certain processes or operations, thence called *chemical operations*.

The properties of natural bodies, whether they be simple or compound, native or factitious, can never be determined *à priori;* they can be discovered only by *actual trial*. When an unknown substance is presented to a chemist for examination, he submits it to certain *trials*, or performs certain *operations* upon it. He examines, for example, the relation of the unknown body to heat, light, water, acids, alcalies, and other liquids. These *trials* have particular *names* given to them, for the sake of convenience in the communication of knowledge. If a substance is exposed to a *red heat*, the operation is termed IGNITION. If the substance *melts*, the operation is termed FUSION. If the substance, on being put into water, *dissolves* or *disappears*, the operation is termed SOLUTION, and the resulting liquid is called *a solution*. If the solution is exposed to heat so as to cause the water to rise *in vapour*, the operation is termed EVAPORATION; or if the operation is so performed that the vapour is collected and reconverted into water, the operation is termed DISTILLATION. If, on the contrary, the solution, instead of being exposed to evaporation, is mixed with some liquid which causes the production of a *solid substance* or powder, the operation is called PRECIPITATION; and if means be taken to separate the solid powder from the residual liquid, by straining through a porous substance, this operation is termed FILTRATION.

The performance of these operations communicates to the chemist a certain degree of knowledge respecting the properties of the substance operated upon. If the substance does not melt when exposed to a strong degree of heat, it is said to be *infusible*. If it does not dissolve when placed in a liquid, it is said to be *insoluble*. A description of the results of a series of such experiments, is the chemical character of the substance. We cannot account for the properties thus found to belong to a sub-

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stance. No chemist can go farther than the ascertainment of simple facts. The sagacity of man is insufficient to determine WHY a given substance is soluble or insoluble, fusible or infusible. The *nature of the power* which causes fusion or solubility, is unknown. And, indeed, this is the case with regard to all physical phenomena, *the forces which produce them are unknown to man, except by their effects.*

The more numerous the operations performed upon a substance, the more accurate is the knowledge acquired respecting its properties; provided the operations be suitably conducted. The properties of a substance can never be wholly known. Chemists begin with a single fact; their daily experience enlarges their knowledge: but, at the best, their acquaintance with the properties of any one body is but limited and imperfect, Not until a substance shall have been submitted to the action of every other substance, and under all possible variations of temperature, pressure, and so forth, will its properties be wholly determined; and that will *never be.* The knowledge we possess respecting the properties of known elements and their compounds, is, notwithstanding the labours of many industrious chemists, still extremely imperfect. No practical chemist, however young he may be in the science, can pursue his studies with even a moderate degree of zeal, without being enabled to add something almost daily to the existing stock of intelligence. The variety of unrecorded facts which continually strike the eye of an industrious experimenter, is indeed surprising.

The first business of a young chemist is to make himself acquainted with what is already known, with what has been already determined by the experiments of others. His next concern, to learn something which no one else has yet discovered.

Chemistry is a science founded so entirely upon experiment, that no person can understand it fully unless he personally perform such experiments as verify its fundamental truths. The hearing of lectures, and the reading of books, will never benefit him who attends to nothing else; for Chemistry can only be studied to advantage *practically. One experiment,* well conducted, and carefully observed by the student, from first to last, will afford more knowledge than the mere perusal of a whole volume.

DIFFERENT CLASSES OF EXPERIMENTS.—Chemical experiments may be divided, for convenience, into three sorts; namely, Determinative, Demonstrative, and Productive.

(a) Determinative.—If any body brings me a substance, and desires to know the nature of it, I must make a *determinative experiment;* in other words, I must submit it to analysis, or *determine* by *experiment,* what it is composed of. Chemical analysis is of two sorts, qualitative and quantitative. A qualitative analysis makes known the chemical nature of the constituents

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of a compound, but not the relative quantities of those constituents. A quantitative analysis makes known both the nature of the constituents and the exact quantity of each by weight. Experiments of this sort are also called experiments of *research*. No man can execute an analysis without previously acquiring a considerable share of chemical information. Before a qualitative analysis can be executed, it is necessary to become acquainted with the properties of all the known elements and their principal compounds, as well as with the methods of determining whether any of them, on a certain occasion, be present or absent. The use of chemical *tests* or *re-agents*, depends upon the knowledge previously acquired, that particular bodies, in particular circumstances, act in a determinate manner. There is, for example, a liquid called oil vitriol. I know that other liquids which contain certain substances in solution, upon being mixed with oil of vitriol, produce a precipitate. If, then, upon dissolving an unknown substance in water, and mixing the solution with oil of vitriol, I obtain no precipitate, I am certified that the substances alluded to are not present. It is evident, that unless I know beforehand what substances *do* give a precipitate with oil of vitriol, and what substances *do not*, it is useless to apply the test; because whether I see a precipitate or not, I acquire no information. A vast number of other substances serve, as well as oil of vitriol, the office of chemical tests, and their employment in chemical analysis constitutes a very important part of chemical study. In the subsequent pages, the reader will frequently find it stated by what diversity of tests a particular substance may be known to be present, and also for what other substances any given compound is able to act as a test.

In quantitative analysis, something more has to be done. Supposing a man to know how to detect all the ingredients of a compound, supposing that he has detected them, he has, in quantitative analysis, the additional task of separating these ingredients from one another, of freeing each from every possible intermixture, and of determining their respective weights. In some cases, two substances can be separated from each other with ease; in other cases, the separation cannot be effected without great difficulty. The methods of separation depend altogether upon the properties of the particular substances which are to be separated, and can only be learnt by studying these properties. But success also depends upon the skill of the operator in the performance of the numerous operations which occur in analysis. The fusions, solutions, filtrations, and evaporations, require to be performed with extraordinary care. If a drop of liquid falls down, or an atom of powder is blown away, the whole experiment is spoiled, and the labour, probably of weeks, is frustrated. To perform an analysis with accuracy, should be the object of a student's ambition, but if he wishes to attain that object he must not only industriously study the properties of chemical bodies, but continually accustom himself to manipulation,

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that he may become dexterous in the performance of those operations upon which the success of an analysis mainly depends.

(b). Demonstrative Experiments are of a different kind. They are employed in the *communication* of chemical knowledge. When a chemist has discovered any thing new, he announces the discovery, and describes an experiment by which the truth of his statement can be proved. This is a demonstrative experiment. There are certain substances which if heated at one end, very soon become hot at the other end; these are said to be *good conductors of heat.* There are other substances which on being heated at one end, are a long time before they become hot at the other end; such substances are called *bad conductors of heat.* A man discovers and states that the metal called platinum is a bad conductor of heat. The proof of this is easy. You take a short wire of platinum, hold it by the fingers at one end and place the other end in the flame of a lamp. You find that the heat comes to the fingers very slowly. This is a demonstrative experiment. As the students of a science must be supposed to be quite ignorant of its facts, it is the business of teachers to demonstrate the truth of their assertions by experiments, and accordingly lecturers on chemistry exhibit a great number of experiments. It would be in vain, however, to attempt, in a class, to demonstrate everything. Want of time forbids it. But a teacher should be careful not to give that as a chemical *fact*, which is *incapable of proof* by a chemical *experiment.* This, however, is a rule which many lecturers make a point of wholly disregarding, and theories of utter extravagance are flung out with a most reckless and prodigal hand. On this account, I caution all students against receiving dogmas as facts, and accepting assertion for argument. I know of no single chemist upon whose judgment I would found my belief. I have stated this before. I have been censured for stating it, and I state it as strongly still. I admit the judgment of no man as infallible. Nobody's *ipse dixit* should pass current in chemistry. In an experimental science, where truth lies within a man's own reach, every person ought to make use of his senses, and judge for himself. Those who are too ready to adopt as their own the opinions of another, are certain to be deceived. It is astonishing to observe the number of false theories which have been propagated by the credulity of idle chemists. Our chemical books contain ten thousand assertions respecting the *proximate constitution* of bodies, of which *not one* is capable of proof. In studying chemistry, therefore, the student should look attentively to the *demonstrative experiments.* No one who is in the habit of reasoning upon what he hears, and believing only what is proved, will ever run the risk of talking absurdities about the properties of *dry nitric acid*, and other chimerical compounds, which nowhere exist but in the excited imaginations of over-credulous "philosophers."

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(c). Productive Experiments. I have given this name to those experiments which have for object the *production* of chemical substances. The *Pharmacopeia* is a collection of productive experiments, containing neither more nor less than instructions for preparing or producing the chemical substances employed in medicine. It will be understood, of course, that many analytical and demonstrative experiments, are also productive experiments; but I understand by the latter term, those experiments only which are made for the express purpose of producing chemical preparation in quantities for use. Productive experiments form an admirable exercise for young students. The preparation of the various acids, oxides, salts, sulphurets, chlorides, iodides, &c., is capable of furnishing most useful information respecting the properties of those substances, and has the farther beneficial effect of habituating the student to careful manipulation. A vast number of substances can be prepared *in the small way*, with the help of glass tubes, small flasks, capsules, glass plates, &c., in sufficient quantities to enable the operator to ascertain their properties and re-actions with other substances. A student's spare time cannot be more agreeably or usefully occupied than in preparing and examining compounds not previously familiar to him. Portions of substances so prepared may be preserved in small pill boxes, or in bits of quill glass tube, closed with corks. Productive experiments in the large way, are those which produce the metals, salts, acids, alcalies, and other commodities of the druggist, the drysalter, the colour maker, &c.

The chemical properties of a substance characterise equally the smallest portion of that substance, or the greatest mass. That which can be demonstrated of a pound, can also be demonstrated of a grain. Hence chemical experiments may be performed, either with large portions of matter, or with small portions; and whether in any case a large or small portion should be operated upon, is a thing to be determined solely by expediency. In trade, where productive experiments are made with a view to obtain preparations for sale, the quantities operated upon are often extremely large, amounting to thousands of tons. In analysis, the quantity of a body submitted to a test weighs sometimes but the fraction of a grain. When a lecturer has to teach chemistry to a large audience, it is his duty to make his demonstrative experiments upon rather a large scale, otherwise a majority of the persons present may not be able to perceive what takes place. And whenever a theory is built upon a single experiment, the lecturer should take particular care to make this experiment in such a manner that every person present may see and comprehend it fully; for if the demonstration is not made to *tell*, the theory sinks unheeded, and the arguments grounded upon it are fustian. I give this hint to the Members of Me-

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chanics' Institutions, who have lately adopted the useful practice of lecturing to one another.

As the demonstrative experiments of the lecture room are unavoidably scanty and unsatisfactory, the student who desires to know somewhat more of the science than he can learn there, must necessarily pursue his studies at home. I have already cautioned him against believing the dogmas he hears and reads, without seeing the experiments which are intended to verify them. It is indispensably necessary, that he perform with his own hands the fundamental experiments of chemistry, in the best manner that his time, his apparatus, and his means admit. He will find it of importance in this case to operate upon extremely small portions of matter; for he will then not only save time and money, but often be enabled to perform a successful experiment, where, by operating upon a large mass, he would as certainly fail. The preparation of the gases, the formation and crystallisation of salts, the application of tests, and a thousand other entertaining and instructive experiments can all be performed by the student, better on a small scale than in the large way; nay more, a student in his closet very frequently succeeds in performing an experiment which fails on the lecture table of the professor; for the accidents which attend the hurry and business of a lecture room produce unavoidable disappointment. This, therefore, is a circumstance of which the chemical student should be prepared to take every advantage. The faculty of experimenting with accuracy, facility, and economy, ought to be gained as speedily as possible; for it is upon that faculty that the progress of the young chemist is principally dependent.

Different Sorts of Chemical Substances.—All natural bodies are either *simple* or *compound*. Those substances are simple, which cannot, by any known method be separated, decomposed, or divided, in such a manner as to produce particles different in their properties from one another, or from the original substances. On the other hand, those substances are compound, which experiment is capable of resolving into particles of an unlike nature. For a period of many centuries, and even till a very late date, there were four substances held to be simple or elementary. These were fire, air, earth, and water. Of these four bodies, all others were supposed to be constituted, though nobody could ever prove, or indeed ever tried to prove, that this was the case. The system, however, continued to be orthodox until very lately, when three of these imaginary *elements*, namely, air, water, and earth, were proved to be compounds. But with respect to fire, it is still unknown whether it be simple or compound, or in what its essence consists, or by what causes its effects are produced. What the ancients considered to be simple bodies are no longer considered to be such; but in place of these substances, the chemists of modern times have elevated to the dignity of elements a far more numerous race. No one, however, dogmatically asserts now a days that the substances

termed elements are absolutely of a simple nature. The term element intimates no more than that the body to which it is applied, has never in the opinion of modern chemists been subjected to decomposition—that it has never been divided into particles different from one another, or from the original substance.

The number of elements is at present assumed to be fifty-four. The properties of these elements, and the experiments by which the separate identity of each is demonstrated, will be described in a subsequent part of this work.

THE CAUSE OF CHEMICAL COMBINATION.—When the elementary bodies are placed in contact under particular circumstances, they unite or combine together, and produce compound bodies. Some combinations are effected very readily, and some with great difficulty, and there are certain elements which can scarcely by any means be made to combine. The compounds produced by the combination of the elements, possess properties very different from those of the elements of which they are composed. The POWER, in virtue of which simple bodies can combine and produce compounds, is one of which the nature is totally unknown to man. Chemists have learned no more than that simple bodies, or bodies supposed to be simple, DO COMBINE; but WHY *they combine*, or *what it is* which MAKES THEM *combine*, they have not discovered. Very frequently, however, the act of combining is attributed to a particular occult power or principle, which is called *Affinity*. If you ask some chemists to tell you *why* bodies combine together, they will say, *because those bodies have an affinity for one another*. But if, on the other hand, you ask the same chemists how they *know* that bodies have an affinity for one another, the reply is, *because they combine together*. These answers show that such chemists have no very clear idea of what they talk about. They confound the notion of the act of combining with that of the power which causes the act of combination to take place. Whether any two given bodies can or cannot enter into combination is a point capable of being decided, either in the affirmative or the negative, by experiment, and by *that alone*. But no experiment, or at any rate, no experiment which has yet been contrived, can show what is the nature of the governing influence which induces, or obliges, any two different bodies to combine together and produce a uniform compound possessed of marked and original properties. What we are told about *affinity* is mere gossip, and though the greatest chemists have given themselves up to gossiping, it does not follow that gossip is to be held sacred or venerable on that account. Wherefore, I caution all young chemists against giving implicit credit to what is said to them about *affinity*, and not to believe any assertion which is incapable of clear conception, or which is repugnant to common sense; nor yet to value that as knowledge and matter of fact, which, upon being closely examined, proves to be mere play upon words. There has been more nonsense written about this affinity, and more ugly diagrams drawn in

illustration thereof, than about any other subject connected with chemistry. And the reason that so much nonsense has been written and published, is, simply, that chemists have been desirous of enveloping their ignorance in a cloak of mystery. There stood the plain fact before the world,—*that bodies combined together, and Chemists knew not why*, but the chemists not liking to *say* so, and not liking even to *think* so, persuaded themselves, and then tried to convince the world, that they DID *know why*. They said that bodies combined together *in virtue of their affinity for one another*. This was pretty. The credulous stared, and amazement gave place to belief.

You prove, by an experiment, that two given bodies are actually capable of entering into combination; you prove, in the same way, that under particular circumstances, two other bodies are incapable of combining together. You inquire what it is which in the one case *causes* the combination to take place, or in the other case *prevents* the combination from taking place. You are told that the first two bodies combine because they have an affinity for one another, and the latter two do not combine because they have no affinity for one another. Now, as you are told, on the other hand, that the existence of an affinity between two bodies is proved by the act of combination, and by that act alone, it is plain that this relation may be expressed in other words, as follows:—the first two bodies combine, *because they combine*, and the last two do not combine, *because they do not combine*. Is there any *use* in this sort of explanation? Does it give you any idea of the power which influences combination? Is the doctrine of chemical affinity anything but twaddle?

I know that bodies *do combine*, but I do not know what it is that makes them combine, or why it is that, in some cases, combination is effected with difficulty, in others with facility. I cannot perceive that any point is gained by ascribing it to *affinity*, which is merely a word without an idea. I consider it sufficient for the communication of knowledge to say, that such and such substances, put together under particular circumstances, either *do* or *do not* combine; and I see no reason for adding the *sham explanation* of the simple fact, that it is BECAUSE the bodies *have* or *have not* an affinity for each other.

Rejecting the doctrine of affinity, *in toto*, it is unnecessary for me to give any account of the multifarious *sorts* of affinity into which the ingenuity of sophists has divided the primary doctrine, or to explain the wonder-working nomenclature applied to it, specially to mislead, perplex, and mystify the ignorant and the unwary:—"Simple affinity—compound affinity—elective affinity—simple elective affinity—double elective affinity—complex affinity—disposing affinity—quiescent affinity—divellent affinity—reciprocal affinity—resulting affinity—*id genus omne*—

"May rosy dreams and slumbers light
Attend you all—good night! good night!"

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PART I.

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CHEMICAL MANIPULATION.

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CHEMICAL MANIPULATION.

By the term Chemical Manipulation, is meant the art of performing chemical experiments. An account of this art may be comprised in a description of the various sorts of chemical apparatus, and of the operations in which they are put to use. I purpose to give that description in the following order.

First, I shall describe, under the head of Pulverisation, the means of reducing solid bodies to small particles, an operation preparatory to all others.

I shall explain, in the second place, the operation termed Solution, the object of which is to bring solid substances into the state of liquids, in which condition they are more easily subjected to the metamorphoses producible by chemical power, than they are when in the state of solids.

I shall afterwards exhibit the sources of different degrees of Heat, and treat of the management of lamps, furnaces, and similar apparatus for producing or applying that power.

I shall explain the contrivances by which different sorts of vessels are Supported, either over fires, or in other desirable situations above the work table.

Then I shall proceed to describe the operation of Testing, whereby the chemist determines the nature of the substances which are subjected to experiment;

Of Precipitation, by which different substances existing together in the same liquid are separated from one another by the conversion of one of them into a solid;

Of Filtration, by which troubled liquids are rendered clear, and precipitates are separated from solutions; and of Edulcoration, by which precipitates, after collection on a filter, are purified by washing;

Of Evaporation, by which solutions are made to yield their solid components in the form of dry powders;

Of Crystallisation, by which particular bodies are converted into those geometrical figures which are termed crystals;

Of Ignition, by which the calcining power of a red heat is made to act immediately upon the object of experiment, to dry, burn, melt, or decompose it;

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Of SUBLIMATION, by which many solids are converted into invisible vapours that soon again assume the solid state;

Of the USE OF THE BLOWPIPE in qualitative analysis;

Of DISTILLATION, by which simple and mixed substances are partially converted into invisible vapours, that subsequently assume the liquid state;

Of the PRODUCTION AND MANAGEMENT OF GASES;

Of WEIGHING AND MEASURING;

And, finally, I shall describe the place where Chemical Manipulation is put into practice—the LABORATORY. This section will comprehend instructions on several operations relative to the construction or repair of Chemical apparatus, such as the blowing and cutting of glass, the boring of corks, and so forth.

PULVERISATION.

Reduction of Solids to Powder, Pulverisation, Levigation, Trituration.—Pulverisation, strictly speaking, is a mechanical operation, as are all the operations which tend to change the form, without changing the nature, of a substance; as, for example, those performed by the hammer, the knife, and the pestle; so also are all those which determine the quantities of bodies:—while the operations performed by the aid of chemical powers and agents,—by fire, water, acids, and alcalies,—and those which separate the constituents of bodies, are chemical operations. Nevertheless, the mechanical operation of pulverisation is so essential to the successful performance of many purely chemical operations, that the right method of executing it is necessary to be familiarly known.—Brittle substances are reduced to powder by means of the *pestle and mortar*,—some by a dexterous use of the pestle round the sides of the mortar; in fact, by *rubbing*, and this is what is termed *trituration*. Reiterated blows of the pestle, which constitutes *pulverisation*, are made use of to powder hard bodies in iron mortars. Only a small quantity of the substance to be powdered should be put into the mortar at one time. *Levigation* is generally performed by rubbing a body, sometimes with the addition of water, on a flat stone, with another stone, round on one side to suit the hand, and flat on the other, which is called a *muller*. A *spatula* or thin flexible knife, of iron, horn, or bone, is employed to collect the substance under operation, from the sides to the centre of the flat stone or mortar. Bodies that are not brittle are reduced to small particles by means of *files*, *rasps*, *knives*, and *graters*.

Mortars are made of a great many different substances; as for example, of wood, glass, marble, porcelain, flint, agate, brass, and iron. In a large laboratory, where a great number of opera-

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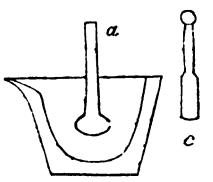
tions are performed, a great variety of mortars are necessary; but those which are most necessary to a student, are a mortar of Berlin porcelain, and another of agate. The porcelain mortar ought to measure 3½ inches across the top. One of this size, is adapted to a great variety of purposes. The agate mortar may measure an inch and a half across the top. One of this size costs about 6s. If the student wishes to have an agate mortar in which to powder minerals for analysis, it ought to measure two and a half inches across the top. The smaller agate mortar is sufficiently large for all blowpipe experiments, and for all cases of qualitative analysis. The bottom of it should be transparent. When an agate mortar cannot be procured, the student should procure a small porcelain mortar in its stead, as it is not convenient to powder very small quantities of a substance in a large mortar. The marginal figure represents a Berlin porcelain mortar of a shape very useful to students. It is two inches wide, and has a narrow spout, useful in transferring powders into small vessels. *a* is the pestle, which is of one piece, and has a broad end. The price of this mortar is 1s. Large mortars, nearly of this shape, but with smaller spouts, are to be had of the diameters given below. The pestles of these are of the shape *c*, and of one piece. The Wedgewood's mortars used in England are very inferior in quality to the Berlin porcelain. The pestles of Wedgewood's mortars have generally a wooden handle, which is a great defect, as dirt lodges in the joint, and sometimes the two pieces come apart.

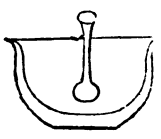


Diameters of Berlin Porcelain Mortars, 2, 3½, 4½, and 5½ inches. *Prices in Glasgow*, 1s.—2s. 6d.—4s.—5s.

Mortars of the above form, of the inferior description of porcelain, which in Germany is called *Sanitaetsgut*, but which, though very cheap, is superior in quality to most English porcelain, are sold in Glasgow at the following prices:—

3½ inches diameter, price . . . . . 1s. 6d.
4½ do. do. do. . . . . 2s.

Annexed is a representation of an apothecary's mortar of Berlin porcelain. It is intended for the pulverisation of large quantities of such substances as are pretty readily reducible to powder. The sizes are mentioned below. These mortars have no spout. The sides converge near the upper part, and the bottom is broad and flat. Hence, the labour of pulverising is much eased, and the substance not liable to be thrown out of the mortar. The pestle is of one piece, and has a very broad end. The mortars can be had either rough or glazed internally. *Diameters*, 5½, 7½, and 9 inches. *Prices*, 4s. 6d., 7s., and 9s.



The agate mortar is employed in the trituration of very hard

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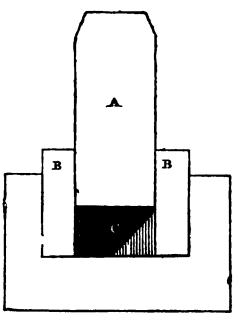
substances, such as minerals. Care is to be taken not to strike it strongly with the pestle; for in consequence of the veins which intersect it, it is very liable to crack and fall to pieces.—The porcelain mortar is employed in the pulverisation of salts, and in the mixture of powders one with another.

As mortars of agate are very expensive when of a large size, mortars of porphyry are sometimes used. These are liable to the accidents of losing crystals of feldspar, in which case they become useless, as the holes cannot be properly filled up. Serpentine mortars are often employed in Germany by apothecaries, in consequence of their cheapness. Mortars of this kind are now imported into Britain; they are, however, not very hard, nor fully proof against the action of acids. The sorts which vary in diameter from 2½ inches to 4 inches cost in Glasgow from 9d. to 2s. each.

In the quantitative analysis of extremely hard minerals, chemists employ a mortar of very hard and highly polished steel, as less liable to abrasion than even agate. The pestle A is exactly adjusted to the ring B, which is also adjusted to the mortar. The ring, however, is made a little conical, that it may readily be taken in and out. The mineral to be powdered is placed in the cavity C, and the pestle is inserted in its place, and struck by a wooden hammer. The pestle is then raised a little, the mortar tapped on the sides to shake the powder into a new position, and the pestle is again struck. Repetitions of this manœuvre reduce the mineral to a fine powder. The iron, rubbed from the mortar, and communicated to the powder, is removed by digesting the latter in diluted muriatic acid. It commonly amounts to ½ or 1 per cent.



As a useful appendage to your establishment of mortars, and even as a substitute for mortars in some cases, I have to recommend you to procure a *small anvil* and *hammer*. The anvil should be a block of hardened steel, about two inches square, and half an inch thick, well polished on the upper surface. The hammer should be also of hardened steel, with a square head, and sharp edges, and the reverse end should be flat and sharp like a chisel. Anvils of this sort are sold under the name of *mineral stakes*. The price of them is 3s. The instrument is very useful in blowpipe operations, and in many others, serving to test the brittleness or malleability of small metallic globules, or to reduce very hard substances to fragments, and thus prepare them for further pulverisation. The hammer serves also to strike fragments from minerals for analysis, and it acts so much the better the harder it is, and the sharper its edges.

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The substance that is to be broken upon the anvil should be first wrapped in paper, to prevent the dispersion of its fragments, when separated by the stroke of the hammer. When a small globule of reduced metal is to be crushed, it should be held down on the anvil by a slip of thin paper placed over it, and secured by two fingers of the left hand. The strokes of the hammer, as many as may appear to be necessary to effect the object, are given upon the elevation produced under the paper by the metallic bead. If the metal is brittle, the powder remains under the paper upon the same spot. If the metal is malleable, it spreads out to a spangle, the edges of which stick so firmly to the paper, that it can be thereby lifted from the anvil for examination.

In mineral analysis, it is of great importance that the substance operated upon be very finely powdered. The state of fineness to which a powder has been reduced, is judged of principally by the appearance. If the body be coloured, the colour becomes paler as the powder is finer, and generally at last almost wholly disappears. When the powder, from being dry and granular, assumes the appearance of moistness, and upon being touched by the spatula, preserves the form given to it by pressure, it is in a state of extreme division. In many cases, the progress of the operation can be judged of by rubbing a little of the powder between the finger and thumb, which is capable of detecting a very slight degree of grittiness. But this trial cannot be made without the loss of a little of the powder. The powder is transferred from the mortar by means of spatulas of platinum, silver, horn, ivory, or smooth paper. A card sometimes makes an excellent spatula, especially if glazed.

When extremely hard minerals are pulverised for quantitative analysis, a few other precautions require to be taken than those above enumerated. But it is not my purpose in this work to show how to manage difficult cases of quantitative analysis; but chiefly to direct your attention to the requisites for qualitative analysis. For the information thus omitted, and for the supply of all similar omissions, I refer you to Rose's *Manual of Analytical Chemistry*.

I shall add here a few words on some operations that are in some degree related to that of which I am treating.

Sifting and Washing are performed to separate the finer particles of bodies from the coarser, which may want further pulverisation. For the operation of *sifting*, the well-known instrument called a *sieve* is employed. *Washing* is used for procuring powders of a more uniform degree of fineness than can be done by means of a sieve; but it can only be used for such substances as are not acted upon by the fluid which is used: the operation is chiefly resorted to, in the pulverisation of very hard minerals for analysis. The powdered substance is mixed with water, or other convenient fluid; the liquid is allowed to settle for a few

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moments, and is then decanted; the coarser powder remains at the bottom of the vessel, and the finer passes over with the liquid. By repeated decantations in this manner, various sediments are obtained of different degrees of fineness; the last, or that which remains longest suspended in the liquor, being the finest. Any cylindrical glass may be used for this purpose.

GRANULATION signifies the division of brittle metals into grains, or small particles, to fit them for different purposes. It is performed either by pouring the melted metal into water from a considerable height, meanwhile stirring the water with a besom, or by shaking it while in a melted state in a box, previously well rubbed with chalk, till the moment of congelation, at which instant it becomes converted into powder.

Cleansing of mortars.—The action of water in cleansing the porcelain mortar can often be assisted by grinding a little fine sand with the liquid in the mortar. Sometimes acids are necessary to take out particular stains. The agate mortar frequently receives numerous metallic streaks when used in blowpipe operations. These can be removed by a little wet bone ashes.

SOLUTION.

SOLUTION is effected when a solid put into a fluid entirely disappears in it, leaving the liquor clear. The body which thus disappears, is said to be *soluble*, the liquid it dissolves in, is called the *solvent* or *menstruum*, and the compound liquor which it produces, is called a *solution*. Sugar and salt are soluble bodies; for when they are put into water, they disappear entirely. Chalk is an insoluble body; for when that is put into water, it only becomes diffused, makes the fluid turbid or muddy for a short time, and then sinks to the bottom. Some bodies are capable of being dissolved in one kind of liquid, but not in another kind. Camphor, for instance, is soluble in alcohol, but insoluble in water. On the other hand, sea salt dissolves in water, but not in alcohol. Hence, if you dissolve camphor in alcohol, and add water to the solution, the camphor reappears in the solid form; and if you add alcohol to an aqueous solution of salt, the latter is instantly thrown to the bottom of the liquid. Metals are soluble, but their *solution* only takes place when they are put into acids. The operation of *solution* is more speedy in proportion as the substance to be dissolved presents a greater surface: on this principle is founded the practice of pounding, cutting, and otherwise dividing the bodies intended to be dissolved. The solution of a body invariably produces cold; and advantage has been taken of this phenomenon, to produce artificial cold, much greater than the most rigorous temperature ever observed in any climate. If you

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grasp in the hand a phial of thin glass, half filled with water, and gradually add to it powdered sal ammoniac, you will find that, as the salt dissolves, the water becomes cold. Solution is much accelerated by heat and agitation. But whether a cold liquid, or heat, or agitation, should be employed in any particular case of solution, must be determined by the nature of the substance operated upon. In making solutions, it is necessary to use a vessel of such materials as shall not be acted upon by its contents, and of sufficient capacity to admit of any sudden expansion, or frothing, to which chemical action may give rise.

Solution is generally performed for the purpose of placing the substance operated upon in a state fit for chemical action. It is of two kinds. The first is that in which the liquid does not act chemically upon the substance which is dissolved. The second is that in which chemical action takes place. Solutions of the first sort reproduce the original substance upon being evaporated, or boiled to dryness, but solutions of the second sort give a substance altogether different.

The fluid most generally employed as a solvent, partly because it furnishes solutions of the first sort, principally because it has a greater solvent power than any other liquid, is water. In certain cases, however, alcohol, ether, oils, acids, and alcalies, are employed as solvents. The solvent powers of different liquids will be investigated in subsequent sections.

A SATURATED *solution* is one in which the liquid contains as great a quantity of the solid matter as it is capable of dissolving. A DILUTE *solution* is a mixture of a saturated solution with pure water. Saturation is affected by temperature. At every particular degree of heat, a solid requires for solution a given quantity of solvent or liquid. But in proportion as the temperature rises, the quantity of liquid requires to be lessened. This effect takes place to an extent, variable according to every solid, beyond which elevation of temperature no longer increases its solubility. This is a general rule, but there are some solids upon which heat has no such effect, and in which the solid and the liquid it is dissolved in, remain in equilibrium at every temperature; while there is a third class of solids, the solubility of which *diminishes* with increase of temperature. It follows from the above facts, that saturated solutions of salts must boil at very many different degrees of heat, each dependent upon the quantity of salt present, and that by ascertaining the temperature of a boiling saline solution, its *percentage* of solid matter may be ascertained, admitting, of course, the degrees of solubility of the salts under consideration, to have been previously determined.

The student should be provided with a variety of vessels for performing the operation of solution, a few of which shall now be described.

Foremost in the list of useful vessels for solution, whenever small portions for Testing are operated upon, stand ***bulb tubes*** and ***test tubes***, such as are represented by the figures on page 8.

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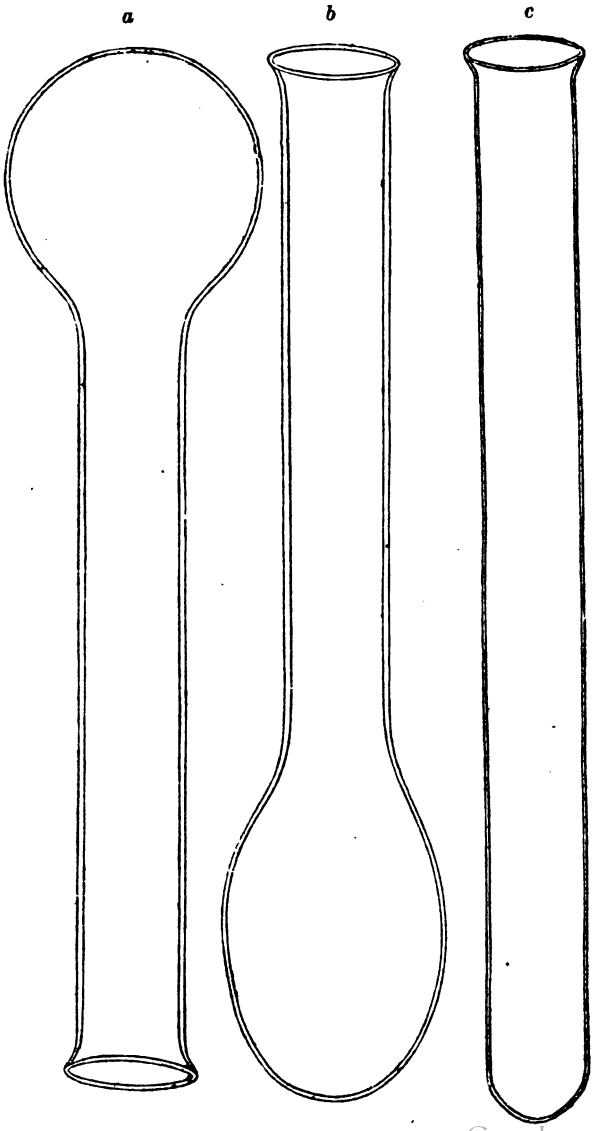

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These should be made of German potash glass, or hard white glass free from lead, or of pale green glass. The bulb of *a* and *b* should be 1 ¼ or 1 ½ inch wide, either round or pear-shaped. The neck ½ inch wide and 4 inches long. The substance of the glass $\frac{1}{30}$ inch thick. The mouth a little turned out, but not so much widened but that, when the tube is held near the mouth with the thumb and middle finger of the right hand, the fore-finger shall be able to close the tube by simple pressure upon the mouth. The figures show the exact size and proportions of good tubes. The cost of these tubes is 1s. each.

The quantity of liquid used in one of those tubes may be half the bulb full. The tube is to be closed by the fore-finger soon after you apply heat to the bulb. It is too late to close it when the liquid has begun to boil. The object of closing the tube is to retain a certain quantity of air above the liquid. This air becomes condensed at the top of the tube by the steam that is produced below; it keeps the tube cold enough to be held by the fingers, and augments by its pressure the temperature of the liquid. But if you remove the finger for a single instant from the tube, the confined air escapes, hot steam rushes forth, and the tube becomes too hot to be held.

Other methods of supporting tubes over lamps will be described in the section on "Supports for Apparatus."

Tubes similar to figure *c*, page 8, may be sometimes used. The mouths of these should be of just such a size as to be easily closed by the pressure of the fore-finger. Straight tubes of this narrow kind, however, only answer for boiling, when very small quantities are operated upon, as, in consequence of their want of capacity, the heated liquor is too apt to boil over. This accident can in a great measure be prevented by holding the tube in a diagonal position over the lamp, so that the flame may strike against the liquid nearer to the surface than to the bottom.

The pressure of the fore-finger upon the mouth of the tube is, however, more to be relied on than any other contrivance, for preventing the boiling over of the solution. If you observe the precaution pointed out in the preceding paragraph, of closing the tube, before the liquid begins to boil, but not till it is just at the boiling point, you will retain sufficient air in the tube, to enable you to hold it without being incommoded by the heat, while you keep the liquid heated up to its boiling point.

If the tube becomes accidentally too hot to be retained by the fingers, you must remove it from the lamp, suffer the boiling to cease, cool the upper end of the tube by the exterior application of wet blotting paper, and then commence the boiling again, with the mouth of the tube closed by the finger.

Very capital boiling vessels also are tubes of the same length and shape as the last figure, but of greater width, say four-fifths of an inch in diameter. These are indeed too large to be held by the hand, because their mouths cannot be closed by the fore-finger, but it is easy to support such vessels over the flame of a

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spirit lamp by the *tube-holder*, of which I shall give a description in a subsequent section. The price of these tubes is 3d. to 6d. each.

Other useful vessels for solution, in small experiments, can be made of glass tubes, besides those already described. The subjoined diagrams exhibit the forms which may be given to such vessels. Figure *a* represents a tube about the size of a quill,

a

the glass of which is about the thickness of an address-card. The tube is closed at one end, and widened out a little at the other, which is open. Figure *b* represents a tube of the same

b

description, with a bulb blown at the end of it, so as to constitute a small matrass. Figure *c* represents a tube of the same

c

description, with a bulb at one end, and a bend near the bulb; the object of which arrangement is to produce a small retort.

The student will find it useful to be provided with a great number of tubes similar to figure *a*, in form, but different in size. They should be from one-eighth of an inch to two-thirds of an inch in diameter, and from 1½ to 6 inches in length. A very useful size is three-eighths of an inch wide, and four inches long. Such tubes not only serve for effecting solution, but may be used as *test tubes*, and can be applied to many other purposes. He who is accustomed to the use of the blowpipe, should employ his spare time in working pieces of glass tube into these very useful forms; and the student who is unable to employ the blowpipe, ought to set about learning to do so without delay. Much loss of time, outlay of money, and practical inconvenience is avoided by him who is capable of preparing and employing these little vessels of glass tube.

The *Florence Flask*, which is represented by the cut in the mar-

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gin, is an instrument of great utility in performing the operations of digestion, solution, &c. It bears the sudden application of heat excellently; but on account of *that thinness*, is very liable to be broken by a slight blow: it therefore requires to be handled carefully. The student should be provided with several of them. They are to be had of oil-men, who sell the empty flasks, after having disposed of the Florence oil they contained. Such flasks are extremely cheap.

The figure in the margin represents a sort of flask, which is much employed by the German chemists. It is made of thin green glass, which withstands equally well the action of heat or of acids. The bottom is turned a little inwards, so that it can stand alone without support, and is made thin, so that it can be exposed to a naked fire. The flint glass bottles sold in this country are much inferior to these continental glasses. Vessels of twice the size of the figure are very useful for effecting the solution of small portions of a substance in qualitative analysis. The price of a flask of ½ oz. capacity is 6d., of 1 oz. 9d., of 4 oz. 1s. The smaller sorts are very thin, and fit for use in delicate experiments on weighed quantities.

The annexed figure represents a bottle extremely well adapted for use in preparing solutions. It is of a good shape, very thin, and quite flat at the bottom, wide in the neck, and with a broad smooth mouth. It came to this country with a sample of *Gallipoli Oil*. Its capacity is 3 ounces of water; its height 5 inches. I have never seen a vessel better adapted to answer the operation of solution on a small scale. The flasks used in Germany, in the preparation of gases, are nearly of this shape, as will be shown in the following pages. Such flasks are now to be had in Glasgow.

In general, bottles made in this country are too thick at the bottom, or, if they are ordered to be blown thin, then the necks are made prodigiously thick, or they are too narrow to allow one to pour from the bottle with convenience, or they are broken off with so many jagged points, that you can scarce handle them without cutting your fingers. Most of the inconveniences here enumerated are avoided in the flint glass flasks now made for sale in Glasgow.

Vessels of the same form as the three last described, but of greater capacity, can be employed when larger quantities of liquid are to be heated.

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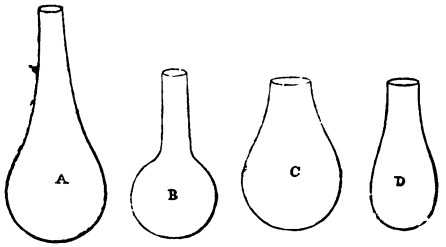
I shall here describe the forms of flasks recommended by BERZELIUS, as generally suited to the different operations of analytical chemistry, and serving, not only for boiling in, but as receivers to use with retorts in the process of distillation. They are represented in the following figures A, B, C, D. When they come from the glass-house they sometimes have long necks, (A,) in which state they answer best as receivers in distillation. But the long neck is an hinderance in boiling, and consequently it is cut off, as shown at C, by a method to be hereafter described.



Very frequently the body of the flask is made globular, as shown at B. This is a good enough shape for receivers, but a bad form for flasks that are to be used in effecting solutions; for whenever the mass which is under operation has to be taken from the vessel, a portion of the solid matter sticks in the bulb near the shoulder or edge where the bulb touches the neck, whence it is often very difficult to be entirely removed. This is particularly vexatious if the operation is a *quantitative analysis*, where any loss of matter is especially to be avoided. By far the best form of flask to be used in analytical operations is that shown by D. It should be of very thin and uniform glass, and have the neck cut off as it is here figured. When it is placed upon the sand-bath, in use, its mouth should be covered with a watch glass. A flask of this form stands with safety on sand, even during a strong boiling. And when the solution is effected, the whole contents of the flask can be readily washed out upon the filter. Nevertheless, for the purpose of preparing solutions in the small way, even this flask is inferior to the flat-bottomed gallipoli oil bottle described at page 11. The price of flasks of German glass of the shape of fig. A, and of 2 oz. capacity, is in Glasgow, 9d, and of 4 oz. capacity, 1s. 3d. Flasks of the same size, but with the mouths bordered, so that they can be fitted with a cork, cost 1s. and 1s. 6d. each.

Prices of very thin Flint Glass Flasks adapted for solution, now prepared for sale in Glasgow:—

WITH ROUND BOTTOMS:—	WITH FLAT BOTTOMS:—
2 oz. fig. D, page 12, ... 5d	2 oz. fig. D, page, 12, ... 7d
3 oz. fig. A, p. 12, long neck, 6d	3 oz. third fig. on p. 11, . . 8d
8 oz. fig. A, p. 12, long neck, 8d	8 oz. second fig. on p. 11, . 1s

None of these have turned lips, but all are thin in the neck as well as at the bottom.

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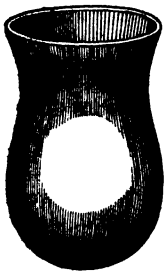
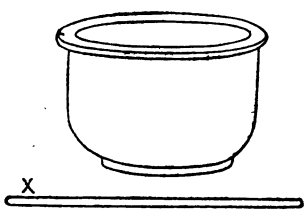
Recently, porcelain vessels for digestion, or solution, have been made at Berlin of the annexed form. The body is shaped like an egg, but at one end there is a wide mouth with a spreading lip, which answers very well for pouring from. Two sizes are made, the smaller $1\frac{3}{4}$ inch wide, and $2\frac{1}{4}$ inches high, the larger $2\frac{1}{4}$ inch wide, and $2\frac{3}{4}$ inches high. They stand very well in sand, or on a triangle, or a perforated plate, over a lamp. They can be closed by a watch glass during the operation, and be readily cleaned when it is over. The porcelain of which they are composed resists changes of heat, and also the action of the solvents generally in use. These vessels have the further advantages of costing only a shilling, and being very durable.

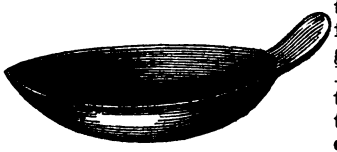


Two little porcelain cups are also made at Berlin, that can be used in digesting small portions of matter. The lesser of these is represented in size and form by the annexed upper figure. The larger is exactly of the same form, but of the width of figure x. When in use, they can be covered by small capsules of porcelain. They suffer heat so well that they can be made red hot without splitting. They resist also, as do all the articles of Berlin porcelain, the corrosive action of acids. The price of these little vessels is threepence.



A third vessel of Berlin porcelain that can be used in effecting solutions, is a capsule, with a spout and a handle, all in one piece. Three sizes are made: 2 inches, $2\frac{3}{4}$ inches, and $3\frac{1}{2}$ inches in diameter. These vessels can be heated either on the sandbath, or on a wire triangle over a lamp, or upon a hot iron plate.

Watch-glasses can often be advantageously employed when the solution of small portions of matter is to be effected, particularly if they are made from window glass, as flint glass is not at all suitable. But an instrument, which, to a great extent, supersedes the use of all small capsules of glass or porcelain, is a capsule of platinum, furnished with a small flat handle or ear of the same metal, and sometimes with a spout. The figures here, and at the top of the succeeding page, represent the full



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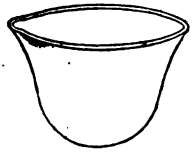
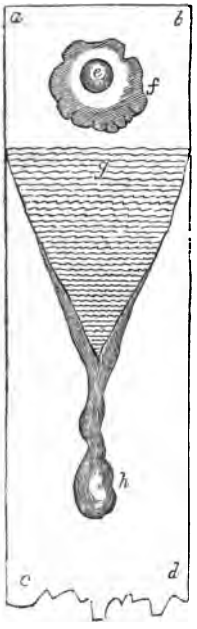
size of the instrument. Another form of platinum vessel, to be used in microscopic experiments, or "thimble chemistry," is that of a cup, either hemispherical, or of the form and the size represented below. These vessels can be supported over the spirit lamp by a thin wire triangle.



Platinum vessels, however, are about twenty times the price of those of porcelain, even when small and thin. Nevertheless this outlay may be made by the student with ultimate profit; for the number of glasses saved from destruction by the common employment of platinum vessels is very great. Glasses frequently break, or suffer corrosion, when heated over a lamp, either with dry matter or concentrated solutions. In every such case, the student loses a vessel and spoils an experiment, while these accidents are obviated by the employment of a vessel of platinum.

There are certain substances which cannot be put into platinum vessels without injuring them. I shall enumerate these substances in treating of the properties of platinum in another section.



Solutions of small portions of salts, earths, metals, &c., for testing, where the experiments are to be on a rough system, may be made on slips of window glass, of the width of the figure *a*, *b*, *c*, *d*, but twice the length, viz., 1 inch broad, and 6 inches long. When in use, the glass is held flat by the end *c*, *d*. The substance to be dissolved, in size not larger than a bead of $\frac{1}{10}$ inch diameter, is placed at *e*, and a few drops of the solvent is put over it, as at *f*. The end *a*, *b*, of the slip of glass is then held above the flame of a lamp till the heated liquid effects the desired solution. More liquid can be added, if necessary, by a dropping tube, to supply the waste caused by evaporation.

The other parts of this figure will be explained at the article "FILTRATION."

This method of making solutions on flat plates of glass is, however, to be regarded only as the last resource of a pinched operator. Any kind of glass vessel that has sides as well as a bottom is superior to a flat plate, and as small tubes can be bought at a penny a piece, flat glass has hardly even the merit of cheapness to recommend it to adoption.

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The insertion of a charge into a tube vessel, and indeed into a flask of any shape, requires to be executed with a proper degree of care. Liquids can be readily inserted by means of a glass funnel, such as is represented in the margin. This funnel is made by blowing a small bulb of half an inch in diameter at the end of a tube, opening it on the upper side, and bending out the edge, and finally drawing a long narrow neck opposite to its mouth. This neck may be 6 or 8 inches long, so as to be able to reach the bottom of most test tubes, and small flasks; or, it may be made only one inch long, and be inserted for use into a straight narrow tube of somewhat greater length than the vessel into which the liquid is to be poured. The same funnel then serves, with the addition of 3 or 4 narrow tubes of different lengths, to pour liquids into all vessels that have long narrow necks, such as tubes, retorts, &c. The smallest size of *filtering funnels* can also be used for this purpose Those of $1\frac{1}{4}$ inch diameter are now made in Glasgow with very narrow necks, in order to answer properly the purpose of fillers. They are more durable than the thin blown funnels.

Powders should be weighed upon highly-glazed post paper, to which they adhere very slightly. They may be poured thence into a tube or flask through a clean dry funnel. If any adheres to the neck of the funnel, it must be washed down by means of distilled water from the washing bottle, an instrument to be described hereafter.

Another method of inserting powders, and one that is especially useful where narrow tubes are to be used, is as follows: You take a slip of highly-glazed post paper, as wide as the diameter of the tube. You fold this longitudinally into a sort of gutter, on one end of which you place the powder. You hold the tube in an horizontal position, and insert the gutter into it, the end bearing the powder first. Then you hold the tube vertically, mouth upwards, upon which the powder falls to the bottom of the tube, and you withdraw the paper.

Whatever the form of the vessel, solution is generally first attempted without heat, and if unsuccessfully, the vessel is then placed on hot sand, or upon a wire triangle over a spirit lamp, or if flat-bottomed, upon the iron plate or the wire trellis of the lamp furnace that is described in a subsequent section.

Upon first heating a bottle, it often becomes wet externally. This wet is to be wiped off before placing the bottle upon the hot iron plate, otherwise the bottle is liable to crack. The bottle should be waved backwards and forwards over the flame of the lamp, then be wiped dry, and again waved over the flame, till no more moisture appears. After this, it may be exposed to the full heat of the flame without danger of cracking, provided the bottom be not too thick.

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DECOCTION.—In pharmacy, a decoction is a solution obtained by boiling vegetable or animal substances in water. A common receipt is one ounce of the solid matter to a pint of water, and the whole boiled down, till the solution, after filtration, measures half a pint. Powerful substances require more water. When a decoction of this sort is boiled down to the consistence of honey, it gets the name of an *extract*.

LIXIVIATION is used for separating such substances as are soluble in water from such as are insoluble. Suppose, for example, it is required to separate the *sand* from a mixture of sand and salt: the compound body is placed in water; the salt is dissolved by the water; the sand is diffused through it. The mixture is filtered; the salt passes through with the water; the sand remains on the filter. The apparatus used in filtration, with the addition of a jug, is all that is required for this operation.

INFUSION is performed when a hot liquor is poured upon a substance that is partly soluble and partly insoluble, in order to extract something from it. The making of *tea* is an instance of the performance of this operation.

DIGESTION.—This operation consists in soaking, for a long time, a solid substance in a liquid kept constantly hot.

MACERATION.—The continued steeping of a solid body in a cold liquid. Ink is produced by macerating the materials of which it is composed.

EXERCISES ON SOLUTION.

1. Weigh out an equal quantity of crystallised sulphate of potash, sugar, sulphate of lime, and sulphate of soda. Boil each in the same quantity of water, and observe the difference in the solubility of these compounds.

2. Make a mixture of starch, sand, sugar, and chalk. Put this into cold water, agitate the mixture, and filter. The cold liquor will contain the sugar. Boil the solid matter in fresh water, in a porcelain capsule. The hot water will dissolve the starch, which may be washed away. After filtration, add muriatic acid to the solid mass, to dissolve and remove the chalk. The sand will then remain alone.

3. Boil gum mastic in alcohol, in a glass tube, closing the mouth of the tube with the finger before applying heat to the tube, to produce an elevated temperature. The resulting solution, largely diluted with alcohol, is a good wash to fix pencil or chalk drawings.

4. Dissolve a grain of copper in six drops of nitric acid, using a tube of the form *b*, page 10. Observe the effervescence that is produced; the production of red gas just above the liquor, the change of the liquor to green, the heat which is produced, the peculiar smell that is disengaged. In one minute the copper will be all dissolved, the liquor remaining green. Blow air into the tube by a smaller tube held in the mouth. This expels the red gas, and turns the green liquor blue. Alternately shake the tube and blow air into it, until the green colour and red gas no more return. The smell goes away with the gas. Look *into* the tube, and not *across* it, to see the colour of the liquor and gas. Next boil the liquor over a spirit lamp. White fumes of nitric acid go away. When the liquor gets thick and pasty, allow it to cool. It will form a mass of blue crystals, proceeding like rays from a centre. This is nitrate of copper. Apply heat; the crystals then melt, get drier, and stick about the sides of the glass as a hard cake.

The salt now decomposes, and a strong smell of nitric acid is disengaged. When the bulb is cold, half fill it with water. Part of the hard matter dissolves, producing a blue solution of nitrate of copper; part remains undissolved as a bluish green powder. This is a nitrate of copper with excess of base, which is insoluble in water. Add a single drop of nitric acid and the whole will dissolve. To the resulting solution, you can apply the different tests for copper.

APPLICATION OF HEAT.

The application of heat has been so often prescribed in the preceding article, that it is necessary to take the earliest opportunity of describing the means by which different high temperatures can be produced and readily applied to the object of experiment. I therefore take up this subject next in order.

The method of applying heat differs according to the intensity of the heat required, to the bulk of the object to be heated, and the length of time during which the heat is to be sustained. It can be conveniently applied by means of a small spirit lamp, a large spirit lamp, an oil lamp, a gas flame, a small charcoal fire, a blowpipe, or a powerful furnace.

SMALL SPIRIT LAMPS.

When you wish to apply a moderate heat, to evaporate a solution of small bulk, to heat the contents of a glass tube, or to ignite a small crucible, you make use of a small spirit lamp. This consists of a short strong glass bottle, the neck of which contains a brass or tin plate tube, holding a cotton wick. The bottle should be nearly full of spirit of wine of a moderate strength. If too highly rectified, it smokes; if too much diluted, its flame is less powerful than it ought to be. The specific gravity should not be above 0.865, nor under 0.84. Spirit of wine of the proper kind burns without smoke, so that a tube does not become soiled when heated in the flame of such a lamp. This is of considerable importance, for when a tube becomes coated with soot, as it does when you hold it over a candle, you cannot see what takes place within it during an operation. The lamp should be furnished with a glass cap fitted to it by grinding, to prevent the evaporation of the spirit when the lamp is not in use. When you want to put out the flame, you clap on this cap as an extinguisher.

Berzelius recommends the wick holder of such a lamp to be made of silver or of tin plate, and not of brass, as the latter is acted upon by the spirit, and partly carried up and deposited as soot upon objects heated in the flame. He also recommends the

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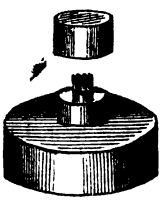
metallic wick holder not to be fixed *within* the neck of the bottle but *around* it, to prevent fracture by expansion when heated.—The prices of glass spirit lamps, with brass wick holders, and of the above figure, are—

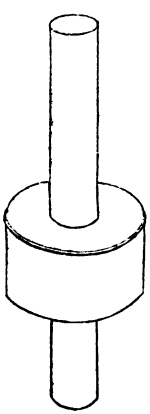
2 oz. capacity, ...	2s. 6d.
4 oz. —	3s.
7 oz. —	3s. 6d.

Or with a pure silver wick holder, 4 oz. capacity, price 8s.

The annexed figure represents a cheap and convenient lamp for small experiments. It is made of japanned tin plate, 2½ inches wide, and 1 inch high, exclusive of the neck, which contains a tin tube one-fifth of an inch wide for the wick. It is provided with a tin cover made to fit the neck as close as possible.



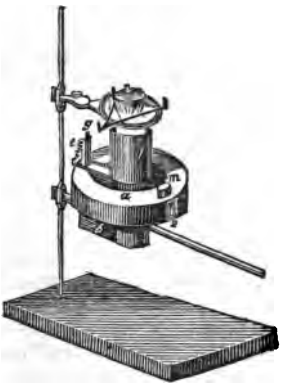
This small lamp serves either to burn oil or spirit, except that for these two liquids a different species of wick holder is required. As it is represented here, the lamp is adapted for oil, being furnished with a very short tube, and having holes both in the tube and in the horizontal piece of tin to which it is attached, intended to facilitate the pressure of the air upon the surface of the oil, so as to make it rise in the wick. When such a wick holder is used with spirit, there proves to be too free a communication between the spirit in the lamp and the external air, and the consequence is, that as soon as the lamp has been lighted a little while, and the tin has got warm, the spirit takes fire at the mouth of the lamp, or at the holes in the wick holder, and burns there as well as at the top of the wick. The way to prevent this, is to have a wick holder of the following description, namely, a tin tube, two inches long, and one-fifth of an inch wide, with an horizontal resting plate, three quarters of an inch in diameter, fixed across its centre, *without air holes*, either in the plate, or the tube, and with a good cork fixed below the plate, and adapted to the mouth of the lamp. This closes the lamp nearly air-tight, raises the flame considerably above the mass of spirit below, and yet does not prevent the rising of as much spirit as is demanded for the sustenance of the flame at the wick. The cover of the lamp requires, of course, to be made deep in proportion to the length of the wick holder. It must grasp the neck of the lamp below the cork. A wick holder of this description can be used to convert any flat broad bottle into a temporary spirit lamp. The little ink bottles sold by the stationers under the name of *thumb-inks*, and which are very cheap, can be used as spirit lamps. By changing



the cork, it can be adapted to either a narrow-mouthed or a wide-mouthed vessel. You increase or diminish the power of the spirit lamp, by making the wick thicker or thinner. It is useful to have one or two spare tubes of different diameters. If you cannot conveniently procure them of tin plate, you can easily substitute a bit of glass tube passed through a cork. The price of the japanned lamps above described is 1s. each.

Another and very cheap variety of small spirit lamp, will be described presently. It is made of clay, and forms part of the lamp furnace.

LARGE SPIRIT LAMPS.



Experiments which require a great degree of heat, such as the ignition of refractory substances, and the decomposition of minerals by fusion with alcaline carbonates, demand the assistance of the spirit lamp with circular wick or double current of air. This is one of the most indispensable instruments of the analytical chemist, for there are many accurate experiments which cannot be performed without it. This lamp is represented in a complete state in the adjoining figure. It is commonly made of brass, but sometimes of japanned tin plate. Its most important parts are as follows:—

The wick *c* passes between two cylinders which are connected below by an horizontal plate, and it can be raised or depressed by means of the toothed wheel *e*, and the toothed bar *g*. The lower end of the latter is connected with a cross bar *o*, upon the end of which a ring is fastened, on which ring the wick is stuck. The cross-bar and toothed rod work up and down in the box *b*. In some lamps the wheel and bar *e g* are omitted, the wick holder being constructed like those of sinumbra lamps. The box *b* does not form part of the spirit holder *a a*, as it does in common lamps, but is separated from it by the open spaces *t t*, or at any rate by a partition on each side. The spirit passes from *a a* into *b* through the pipe *k*, which forms the only communication between the spirit holder and the box which holds the wick. The object of this contrivance is to prevent the explosion which frequently takes place when the common spirit lamps are inflamed, and which is owing to the inflammation of the mixture of atmospheric air and vapour of alcohol which forms in the spirit holder *a a*. At

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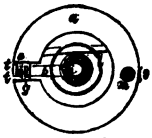


m is an opening by which the spirit is poured into the lamp. This is afterwards closed by a cork, or a screw. A piece of glass is cemented in the front of the lamp, at *s*, to afford an opportunity of readily ascertaining how much spirit the spirit holder *a* contains. The lamp is provided with an iron chimney, *l*. By raising or depressing the wick, the flame is increased or diminished. The air is brought to the spirit, externally by the side, and internally by the canal *i*. The wick must be cut quite level, and must never remain in a charred state. When a lamp is constructed in this manner, and according to the following scale:

1 Foot.

it affords heat sufficient to fuse 380 grains of carbonate of soda in about fifteen minutes, supposing the salt to be contained in a platinum crucible of the weight of from 300 to 380 grains, and large enough to contain an equal weight of water. A lamp which is incapable of effecting the fusion of at least 180 grains of carbonate of soda, though useful in a great many experiments, is not powerful enough to be generally employed in the analysis of minerals. The experimental chemist ought to possess two lamps of this description; one for fusing, and another for other experiments. In the latter case, the rods which support the lamp may be strong, but for the fusing lamp, the rods must be made as thin as possible, in order that they may not carry away too much of the heat.

Some improvements have recently been made upon this lamp, which are not shown in the above figures. The first is a hinge for the chimney, upon which it is fixed in such a manner as to be readily turned *upon* or *from* the flame. The second is a hinged door which closes the mouth of the wick holder when the flame is extinguished. The third improvement consists in the application of a sort of dome or jacket, to protect a heated crucible from the free air. I shall describe it in the article "Ignition."

The cost of this kind of lamp, complete, with stand and rings, and well finished, is about 25s. A powerful lamp with feet, made in Germany for the use of apothecaries, costs 31s. 6d.

With a lamp such as I have described, all grades of heat can be obtained, from that which keeps a liquid gently digesting without boiling, and which is produced by depressing the wick till it gives only a small blue ring of flame, up to the heat which is sufficient to melt a small silver crucible. The applications of this lamp are therefore so extensive, that it becomes an indispensable instrument to every one purposing to undertake anything like a course of effective experiments. In a vast number of cases, it prevents the necessity of employing furnaces; for it affords sufficient heat even for the decomposition of many minerals by fusion with carbonated alcalies in pretty large platinum crucibles, and for effecting many other results, which,

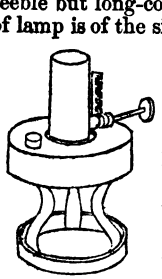
before the invention of this lamp, required the employment of charcoal fires.

In France and Germany, spirit of wine is very cheap, but in England it is very dear, in consequence of the excise duty. This is an unfortunate restriction upon the industrious pursuit of analytical chemistry by English students. Many who have more zeal than money, attempt to perform imperfectly with oil-lamps, what foreign chemists perform perfectly with spirit lamps. This must continue to be the case until an alteration takes place in the excise laws. There is no doubt that the progress of experimental chemistry is retarded in this country by the simple circumstance just alluded to.

In consequence of the dearness of spirit of wine, a liquor sold under the names of acetic naphtha and pyroxilic spirit, and which is a secondary product obtained in the manufacture of vinegar from wood, is frequently made use of. It answers the purpose of combustion very well, and is cheaper than spirit of wine; but it diffuses in the apartment where it is used a very strong and (to me at least) disagreeable smell. It has also the property of speedily rotting cork, and therefore of loosening the wick holders of the small lamps described above. And finally, when used in a large copper lamp, it soon destroys the cotton wick. For these reasons, I recommend spirit of wine in preference to pyroxilic spirit.

OIL LAMPS.

Oil lamps are in general only employed when you require a feeble but long-continued heat, and for this purpose the best sort of lamp is of the simple kind described at page 18, without chimney or central air pipe. The argand lamp is, however, sometimes recommended as useful in chemical experiments, and is made for sale of the form shown in the annexed figure, and provided with a copper chimney. But the operations are very few in which these lamps are really useful. For evaporations and digestions they give too much heat, and for ignitions by far too little. For operations that require a strong heat, they are replaced by the large spirit lamp which I have just described, and for other operations that require less heat, by the smaller spirit and oil lamps.



I have already described a small lamp adapted for burning oil. I now subjoin a description of another lamp employed for the same purpose by Berzelius.

The form of oil lamp which, he says, "I have found to be most convenient for chemical experiments," is depicted in the margin. It is broad and low, and on that account burns to the end without any diminution of flame proceeding from scantiness

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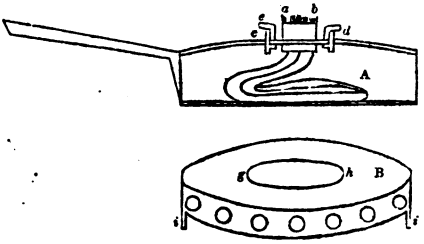

of oil. There is no want of draught. The wick *a b* is flat and broad, so that the lamp gives a good light. The wick holder is soldered to a flat plate which can be fastened in the neck of the lamp *c d*, by means of the screw *e f*. A ring of leather between the screws closes the mouth tight, so that no oil can escape when the lamp is turned about in various positions, or even when it falls to the ground. Such a lamp is very useful at night, to give light at any particular part where a person is filtering or carrying on any other operation, in a place not sufficiently lighted by the ordinary illumination of the apartment.

You have to observe, in relation to an oil lamp, that when it deposits soot on the vessel placed above it, there is scarcely any heat transmitted. You must, therefore, pull up the wick only so far as allows the lamp to burn without smoke. If you have good oil, a lamp of the sort now described will burn for hours together without needing snuffing, a circumstance of considerable moment.

Currents of air in an apartment, proceeding from open doors, or from the movements of the experimenter, hinder a lamp from burning with a steady and even flame. This can be remedied by placing a small chimney over the flame, for the support of which chimney, the ring B is employed. The ring is filled with holes to admit air. It has a top with a circular hole in its centre *g h*, rather larger than the ring *e f* of the lamp A. Below, it has three feet, *i i*, by which it is held steadily on the lamp. When this ring is placed on the lamp, the air for the support of the flame passes through the ring of holes, and presses towards the wick, between *g h* and *e f*. A short cylinder, either of metal or of glass, such as a piece of a retort neck, is placed over the flame, and so as to rest upon the upper plate of the ring. The length and width of such a chimney can be varied according to circumstances.—Thus far Berzelius.

I find that if a cotton wick, which is to be used in an oil lamp, is first soaked in strong vinegar, and then dried, before insertion in the oil, the crusting of the wick, and the consequent necessity for frequent snuffing, is entirely prevented. Those who use sinumbra lamps for domestic purposes will find this practice to be worth their attention.

The oil called *droppings of sweet oil*, is the kind that is best adapted for chemical lamps.

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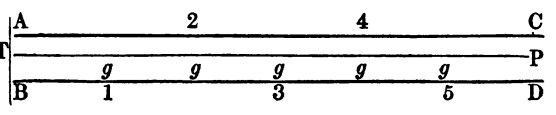
GAS.

A CONSIDERABLE number of experiments requiring only a moderate degree of heat, and a good many also of those which require a high, but not an intense, degree of heat, can be executed by those who have command of *gas*, without the use of any other fuel. It is convenient, where it is possible, to have the gas pipe come from below, up to, and terminate at, the surface of a table, so that burners of different kinds, such as a simple jet, or a powerful argand, or a blow-pipe nozzle, can be screwed on or off as required. Where it is not possible to have the gas pipe fixed in such a position, the next best arrangement is to have a flexible tube affixed to the pipe, with a termination adapted to rest steadily on the table at any required spot, and to receive burners of the above-mentioned varieties. I shall give a description of such an apparatus in a subsequent chapter.

I should mention in this place, for the information of teachers who may be induced to give lessons on practical chemistry to large numbers of persons at once—for example, to the members of Mechanics' Institutions, or to other classes of students—that a convenient method of substituting gas for spirit-lamps has been pointed out by Dr Reid of Edinburgh.

A long plank, a foot broad, and two inches thick, is supported horizontally at about three feet above the floor. A gas pipe is fixed upon the centre of the upper side of this plank, and runs its whole length. At fifteen or eighteen inches' distance from each other, there are upright jets arising from this gas pipe, the whole of which are under the control of the teacher, who stands at one end of the plank, where there is a stop cock to regulate the issue of the gas.



A B C D represents the upper surface of the plank. P is the gas pipe running down its centre. *g g g g g* represent the jets of gas. T is the position of the teacher, who is able to see every thing that is transacted the whole length of the board. The pupils who are to be exercised in experimenting, stand on each side of the board, one opposite to each gas light, as shown by the numbers 1, 2, 3, 4, 5.

When the number of pupils is considerable, it is necessary to use two planks instead of one. In this case, they should be placed so as to converge where the teacher stands, and present the shape of the letter V.

I shall, in a subsequent section of this work, present a course of elementary experiments adapted to be executed by a large class of students, superintended upon this system.

Most of the experiments that are commonly performed over

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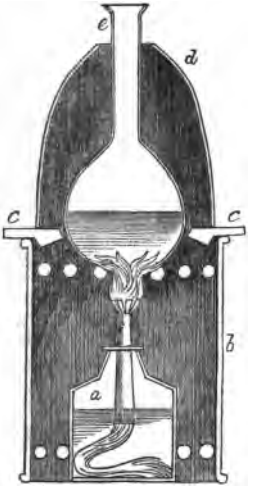
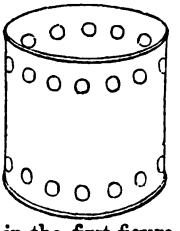
the small oil lamp, and small spirit lamp, can be made over the gas flame; but it is not possible, by any form of burner yet introduced, to effect with gas those fusions and decompositions for which the large spirit lamp is recommended. There is a want of intensity in the heat of the gas flame, which renders it inadequate to this end. Consequently the large spirit lamp is valuable even where the operator has command of gas; and it is still more valuable where, as in Glasgow, it is difficult and expensive to procure charcoal for furnace operations.

LAMP FURNACE.

I GIVE this appellation to a set of apparatus adapted to expose vessels of different sizes and shapes, in a convenient manner to the heat of a small flame, produced by spirit, oil, or gas. A section of the chief parts of this apparatus is shown in the margin, as connected for use; but the articles belonging to it altogether amount to eight, and are as follows:

I. *A cylinder, open at both ends*, five inches long, and four inches wide, with a double row of holes round it, each hole being half an inch in diameter, and half an inch apart from the others, and each row of holes half an inch distant from the end of the cylinder. Letter *b* in the above figure, shows a section of this cylinder, and the annexed outline represents it in perspective. The material of which it is made is salt glazed firestone, of about the fifth of an inch in thickness.





II. *A spirit lamp*, represented by *a* in the first figure This is made of salt glazed firestone. It is of a round form, 3 inches wide, 2 inches high to the shoulder, and 3 inches to the top of the wick holder. The latter is made of tin plate, in the manner of the wick holder represented at page 18. It is depicted in the above cut, as being slightly conical, which is the form given to the wick holders of small spirit lamps by the German chemists, but I do not find it to be better than the cylindrical wick holder. This spirit lamp is provided with a cover, made of fire

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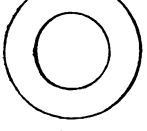
clay, and of the form shown by figure *a* page 17. The inside of this cover is adjusted to the neck of the lamp by being lined with pasted paper. The wick holder is kept in the middle of the neck by a cork fixed upon the tube under the flat plate, but not represented in the cut.



III. *A flat ring*, of the figure shown in section by *c c* in the first figure, and shown by the outline in the margin as when seen from above. It is made of salt-glazed firestone, is 5 inches in diameter, and has in the middle a hole 3 inches in diameter. It is $\frac{1}{2}$ inch thick, and has on the under side a projection shewn by *c c*, which serves to fix it on the cylinder *b* in the same manner as we fix on the lid of an earthenware tea-pot. The hole in the middle of the ring is rather wider above than it is below, the sides being cut aslant that they may the better fit the round bottoms of flasks and capsules.

IV. *A dome*, represented in section by *d* in the first figure. It is made of salt-glazed firestone, is 4 inches high, $3\frac{1}{2}$ inches wide at the bottom, and $1\frac{1}{2}$ inch at the top, open at both ends, and $\frac{1}{2}$ of an inch in thickness.

These four articles are sold in a set for one shilling and sixpence, complete as exhibited by the first cut, with the exception of the flask marked *e*. In circumstances, where it may happen that this firestone apparatus cannot be procured, you may supply its place by similar articles made of tin plate, which however, are less durable in consequence of their liability to suffer from rust, and at the same time cost twice the price of the firestone. The cylinder when made of tin plate should be strengthened by a strong wire soldered round each extremity. The lamp may be supplied by the glass or tin lamp formerly described, or by a jet of gas. The flat ring can be replaced by a perforated tin plate, 5 inches diameter, either round or square: the former is perhaps the neater shape, but in actual operations, the corners of the square plates are not useless; since being generally cooler than the rest of the plate, they serve as handles by which the plates can, if requisite, be lifted and removed. The dome may be supplied by a truncated cone of tin plate, 4 inches high, 4 inches wide at the bottom, and $1\frac{1}{2}$ inch wide at the top, so as to resemble a funnel wanting its neck.

I proceed to describe the other portions of the lamp furnace.

V. *A piece of thick tin plate*, 5 inches square, the price 2d.

VI. *A piece of iron wire trellis*, 5 inches square, the price of it, 4d. The size of the wire and the meshes are the same as shown by fig. A. In the event of your finding it difficult to procure wire trellis of the degree of fineness shown by figure A, which is, however, now easy to be got in most large towns, you can at all events readily construct a substitute for the trellis, by knitting iron wires of the thirtieth of an inch in thickness into the form shown by the figure B. (See the figures on page 26.)

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Fig. A.

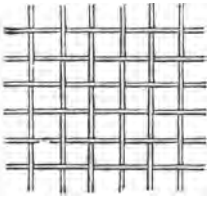
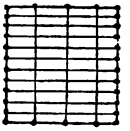
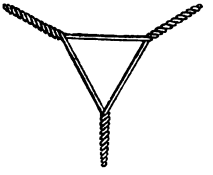


Fig. B.



VII. *A pan of tin plate*, 5 inches in diameter, and 1 inch deep. It may be round, square, or oblong, but it must be formed of one piece of metal, with the edges turned up, and beat together at the corners, so as to be tight without solder. The price of such a pan is 6d. or 8d. A shallow capsule of tin plate or copper, 5 inches in diameter, and 1½ inch deep, answers the purpose better, and only costs a few pence more.

VIII. *A triangle of iron wire* of the subjoined form, made of wire not exceeding $\frac{1}{20}$ of an inch in thickness. There should be several sizes of this article, in which the length of the sides of the triangle should vary from 1 inch to 2 inches. The straight legs of each should be just long enough to rest steadily on the flat ring (III.) when the triangle is placed over the centre of the perforation in the ring.



Use of the Lamp Furnace.—Such is the Lamp Furnace. I proceed next to describe its uses.

a. To boil in a flask, the bottom of which is round, and the middle of which is 3 inches in diameter:—Put the cylinder around the lamp, place on it the flat ring, fix the flask in the hole of the ring, and cover it with the dome. The cylinder keeps the flame of the lamp steady by protecting it from currents of air, and it supports the ring, the ring supports the flask, the dome retains the heat communicated to the flask, keeps the cold air from it, and thereby considerably increases the heating power of the lamp. It thus answers in some respects the purposes of the dome of a reverberatory furnace. When the jacket is of tin, it should be kept bright.—Four ounces of water contained in a Florence flask, placed over this small lamp, boils in less than five minutes. Hence this furnace affords as great a degree of heat as is required by a student in making solutions of most salts for qualitative analysis. A much greater quantity of a liquid can be boiled within a given time over a spirit flame, with the aid of this apparatus, than when the same flame is employed in the open air, and the vessel suspended over it by a retort holder; and consequently, a given quantity of a liquid can be boiled with a less consumption of spirit with this appara-

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tus than without it. There are, therefore, two objects gained by using this apparatus—the operation is quickened, while an expensive fuel is economized.

b. To boil in a flask, the bottom of which is round and the middle less than 3 inches in diameter.—When the vessel is of smaller diameter than the perforation in the flat ring, it is necessary to support it by means of a small triangle of thin iron wire, (article VIII.) placed across the hole in the ring, or an extra flat ring of pottery, with a hole $1\frac{3}{4}$ inch in diameter.

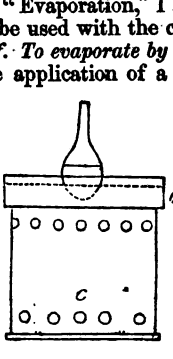
c. To boil in a flask with a flat bottom (such as those shown at page 11.) Instead of using the flat ring, you cover the cylinder with the iron trellis (VI.), or with the tin plate (V.) The former when a quick heat, and the latter when a moderate heat, is required.

d. In evaporation. When you desire to confine the heat of the lamp chiefly to the bottom of a capsule, as in evaporation, performed to concentrate a solution for crystallisation, you use the flat ring. For purposes of this sort, you can supply yourself with extra tin plates having holes of different diameters to suit capsules of different sizes; but a hole of 3 inches diameter will admit four capsules of sizes much employed in small evaporations; namely, the Berlin porcelain capsules with turned edges, which measure respectively $3\frac{1}{4}$, $3\frac{1}{2}$, $3\frac{3}{4}$, and 4 inches in diameter.

If you desire the capsule to be exposed to a more gentle and general heat, you employ the flat tin plate (V.) which affords a heat very useful in gentle evaporations, and can be advantageously employed with the small oil lamp.

e. To evaporate, or to dry, by a water bath.—In the article on "Evaporation," I shall describe a small water bath, adapted to be used with the cylinder of this Lamp Furnace.

f. To evaporate by a sand bath.—When an operation requires the application of a sand heat, as in some distillations, and in the evaporation of solutions for crystallisation, you place upon the cylinder the pan (VII.) filled with sea sand, previously washed to free it from dust, and sifted to free it from stones. If opportunity offers, the sand may be heated in an iron ladle over a common fire previous to use upon each occasion. This economises the use of the oil or spirit. Annexed is a figure of the Lamp Furnace with a sand bath in operation. *c* is the cylinder, and *a* the sand bath.



g. To evaporate, or to dry, by a current of hot air.—When the lamp is lighted and the apparatus put together as shown at page 24, the flask *e* being omitted, there passes from the upper end of the dome a rapid and regular current of hot air, which you can lead in any direction by a bent tin pipe, or which you can often

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advantageously use by placing a second cylinder and flat ring upon the top of the first, retaining the dome within the second cylinder, and placing the vessel that is to be heated upon the upper flat ring.

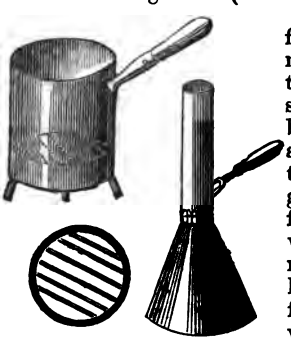
h. Ignition.—When a small crucible or porcelain cup requires to be made red hot, it should be fixed at the point of the spirit flame, supported by a very thin iron wire triangle (VIII.) placed across the hole in the flat ring, and surmounted by the dome.

Other applications of the Lamp Furnace will be pointed out as I describe the operations that require the assistance of heat.

FURNACES.

When you want to ignite a large crucible, or to evaporate a large bulk of liquid, or for any other purpose to apply heat over an extensive surface, it is best to employ a charcoal fire, contained in a *chauffer*, or furnace of iron plate.

The Chauffer.—The figure represents a furnace constructed on the following scale: (———— 1 Foot.)



A grate (represented by the lower figure on the left hand) is fixed near the bottom of the furnace, and the whole is supported on three short feet to permit air to enter below the grate. Holes may be also pierced round the lower end of the furnace between the feet and grate. The funnel-shaped vessel is formed of iron plate, and serves, when placed over the furnace, to make the fire burn fiercely. The handle is of wood, fixed on an iron fork. You should be provided with a round flat grating made of iron wire, with meshes $\frac{1}{4}$ of an inch in diameter, which on being placed upon the furnace serves to support flasks and capsules which may be exposed to the fire. You should also possess several round flat pieces of iron plate rather larger than the top of the furnace, with holes in the middle from $1\frac{1}{2}$ inch to 5 inches in diameter, adapted to receive capsules and other vessels to be heated.—See the perforated plates, pages 24, 25.

When you wish to have a *sand bath*, place upon the above furnace a pan of plate iron, 12 inches square and 2 inches deep, half filled with washed and sifted sea sand. A chimney must pass up through the sand pan, or a couple of iron bars be placed between the pan and the top of the furnace, otherwise the fire will not burn well.

A chauffer of another form is described in "Ede's *Practical Facts in Chemistry.*" Its shape is an inverted truncated cone; its dimensions, 6 inches diameter at the upper (broad) end, and

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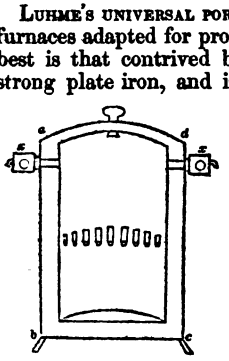
2 inches diameter at the bottom, where there is a grate; the depth from the top to the grate is 3 inches. The sides are pierced with numerous holes half an inch wide. It is made of iron plate, and is supported on an iron ring, surmounting three iron legs.

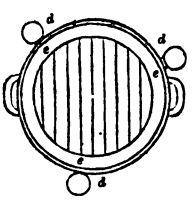
The charcoal used for these furnaces should be in small pieces, not larger than a cubic inch, and free from dust.

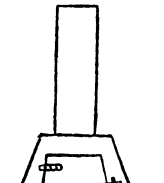
When small furnaces are used upon tables, they should be placed upon a pretty large iron pan, supported by one or two tier of bricks. If this be not attended to, the heat, or the falling ashes, may set the table on fire.

LUHME'S UNIVERSAL PORTABLE FURNACE.—Among the varieties of furnaces adapted for producing high degrees of heat, one of the best is that contrived by *Luhme* of Berlin. It is prepared of strong plate iron, and is represented in the following figures.



a b c d is the iron envelope, upon the upper end of which is a flat rim of iron of the width of the mass of fire clay with which the iron cylinder is lined. *g* and *h* are doors; *g*, the ash pit door, is provided with a small central door, which can be opened or closed at pleasure. *x x* are two round openings opposite to each other, and intended to afford passage for a tube. These openings can be closed by the two little doors that are represented in the section as standing open, but provided with clay plugs to stop up the holes when they are shut. The adjoining figure shows the furnace as seen from above. The parallel lines in the centre represent the grate. At *e e e* there are three iron knobs which project a little way beyond the fireclay and serve as supports for kettles, &c., that are smaller than the opening of the furnace. These knobs are not seen in this figure, but are shown in the figure above. The three flat plates *d d d* serve on the other hand to support vessels that are larger than the mouth of the furnace. In both cases, therefore, the vessel is supported without impeding the draught of the furnace. The next figure represents the dome, with its





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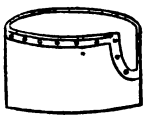
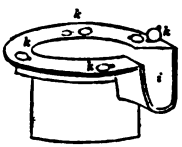
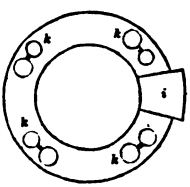
chimney. The dome, like the furnace, is lined with fireclay, and is provided with a door, which also is lined with fireclay.

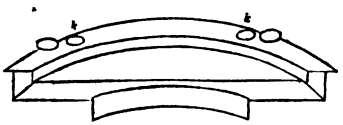


When the furnace is to be employed in a distillation, it is first raised by means of an iron ring of the form exhibited in the margin, and which is exactly adapted to *a d*, the upper part of the furnace. Upon this ring the sand bath is placed. This has a very peculiar form, and is represented by the two figures below, whereof the one on the right hand is a view from above, and that on the left a perspective view. The neck of this sand bath fits into the ring above figured, so as to leave a space between them. There is an opening on the side, *i*, adapted to receive the neck of the retort, the body of which rests in the sand. There are openings on the margin of the sand bath to admit the escape of air from the furnace, and thus keep up the draught, and this can be further regulated by the covers for these openings, *k k k k*. By means of these doors the heat can be increased or diminished at pleasure. Distillation by retorts placed in this sand bath, proceeds with regularity and certainty, as the operator, by means of this power of regulating the draught, added to that of properly administering the fuel, has the intensity of the heat completely under control. There should be a species of conchoidal cover of iron plate made to fit the top of this sand bath, and having a piece cut out of one side to permit the egress of the retort neck. The object of putting this over the sand bath is to prevent the cooling of the body of the retort by too free an exposure of it to atmospheric air.





Finally, this figure exhibits a section of a sand bath with a large surface, adapted for the same furnace, and useful in evaporation, digestion, and other similar operations. The draught is regulated by the openings and lids, *k k*, of which there are four in the circumference.



The price of a furnace of this description in Glasgow, with the deep sand pot and dome, but without the flat sand pan, or the openings *x x*, is £2. The internal diameter of the furnace at this price is 5 inches.

WIND FURNACE.—I shall now describe a furnace which is employed for fusion, distillation, roasting of ores, and other operations that require a very high temperature. It is called a wind furnace. This apparatus is altogether indispensable for

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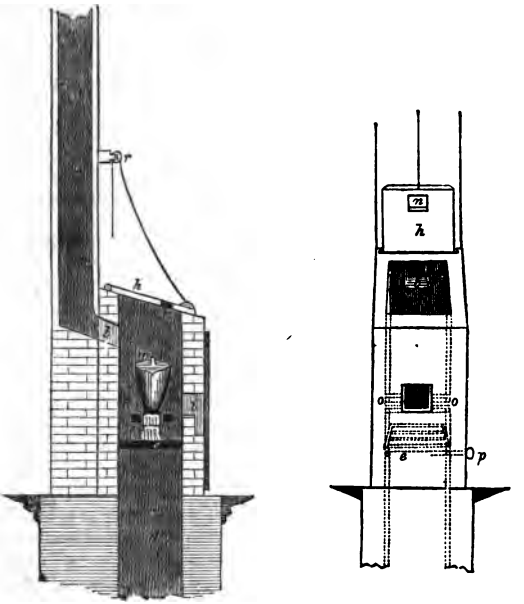
many important chemical operations, although not necessary for the elementary experiments of a student. I give the description because it may be useful to students who have access to a regular laboratory.



Wherever it is possible so to do, it is advisable to make an opening in the floor where a wind furnace is to be built, and so to contrive the building that the ash-pit of the furnace shall be in the cellar whence the draught is to come. The inner body of the furnace may be either round or square. In crucible operations, fuel is burnt to waste in a four-cornered furnace; but on the other hand, this form is preferable to the cylindrical for distillation and roasting. In the figures, therefore, the four-sided furnace is depicted. The cross section of the interior of this furnace is a square of which each side measures 18 inches. At *e* is the grate, consisting of several bars of cast iron bound together and turning upon a hinge. The opposite side of the grate, to that which is connected with the hinge, rests upon a bar *p*. This bar is moveable and can be withdrawn by pulling the knob outside the furnace. In that case the grate falls down, hangs perpendicularly by the hinge, and lets the coals fall into the ash-pit. Below the grate, a canal, *d*, of the same width as the upper part of the furnace, descends about two feet and terminates in the

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cellar. Above, the furnace is closed by an iron plate, *h*, lined with fireclay, and fastened to an iron chain, by the help of which, and a pulley, *r*, it can be pulled open when it is necessary to throw in fuel, or to stir the fire. There is a small hole, *n*, in this plate, which can be covered with a moveable iron plate. The use of it is to afford an opportunity of occasionally observing the fire. From the body of the furnace, the hot gases pass into the chimney, *c*, by the canal *b*; the cross section of the chimney, like that of the furnace, is a square. The proportions observed in the above diagram are taken from a furnace which was employed in the preparation of potassium by the ignition of carbonate of potash with charcoal, and which gave over the potassium in 20 or 30 minutes. The chimney of this furnace was upwards of 50 feet high. This description is given in *Mitscherlich's Lehrbuch der Chemie.*

The opening, *b*, between the furnace and the chimney, is commonly made rather wide, and can be diminished more or less, according to the operation, or the difference in the fuel employed, by the insertion of pieces of fire brick.

The chimney is provided with a damper for the regulation of the draught.

When the furnace is to be employed to effect a fusion, the opening *i* is closed with a brick. Another brick is placed upon the grate, and the crucible upon the brick.

When a substance is to be heated with access of atmospheric air, as in *cupellation*, you employ a piece of apparatus termed a *muffle*, which has the shape figured in the margin, and is made of fireclay. This is placed upon the bars *o o* in such a position that its mouth opens into the cavity *i*. The substances which are to be heated in the presence of air are placed in small capsules upon the floor *b* in the muffle. The muffle is kept red hot, and the air, entering at the opening *i*, passes into the muffle at *b*, and escapes by the openings *a a a* into the chimney. The action of the air upon the heated substances is promoted by agitating them.

When the furnace is to be used in distillation at high temperatures, as in the preparation of zinc or potassium, the retort or bottle is placed upon the bars, *o o*, and the opening *i* is closed by a brick, in which there is a hole for the neck of the retort.

In all cases it is preferable that the ash pit of this furnace should be in the cellar, because the heat of the falling cinders is then not diffused in the room where the operator is at work. Besides, it is often necessary to diminish or to extinguish the fire suddenly. This is done by simply withdrawing the bar *p*. Such an arrangement is peculiarly desirable with a furnace, which, like this, is employed in the preparation of large quantities. It adds to the safety and certainty of the operations.

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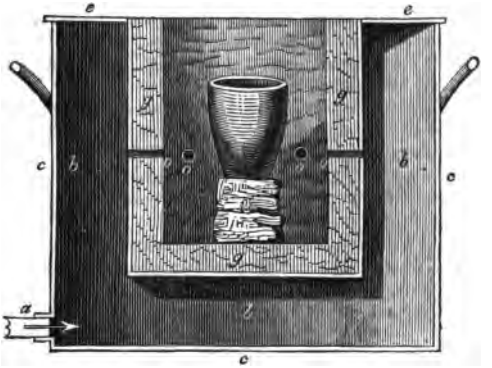
Blast Furnace.—The highest degree of heat is produced in a furnace into the middle of which air is forcibly blown from many different points at once. Such a furnace is best formed of two iron cylinders, placed one within the other, as shown in the following cut, where *c c c* represent the outer cylinder, and the inner is shown lined with, *g*, a thick mass of fireclay. Both cylinders are provided with a bottom, and are fixed together at the top, air-tight, and in such a manner as to leave an equal space between their bottoms and sides. This is exhibited in the figure. The smaller cylinder and its lining of fireclay, is pierced



near the middle of the sides with eight holes, all pointing towards the centre of the furnace. The crucible to be heated, is placed upon stones in the middle of the furnace. The air is blown in at the opening *a*, which is connected with the bellows; it is thus compressed in the space *b*, and thence driven through the holes *o o* into the middle of the furnace. The heat thus produced is very intense. In a furnace, proportioned as above, and measuring 27 inches from *c* to *c*, half a pound of feldspar can be completely melted in half an hour. Iron and other substances of difficult fusion melt in it with ease. The fuel used for this furnace requires to be very uniform in size, to be all, for example, of the bulk of a cubic inch. This uniformity is gained by breaking the fuel to nearly the size required, and then sifting it through two sieves, one of which retains all the pieces that are too large, and the other lets through all that are too small. If coke is used, it must be of a sort that gives very little ashes. The crucibles that answer best are the Hessian; but neither these, nor those of plumbago withstand entirely the melting power of this furnace.

All furnaces must be placed under a suitable vent, so that smoke and fumes may be carried away by the draught, and no mischief be produced by ejected sparks or hot cinders.

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In different localities, different modes of producing and applying heat are preferred from accidental differences in cost and convenience. In most parts of Germany, for example, both spirit of wine and charcoal are cheap, and coal gas is not in use. In Scotland, on the contrary, gas is cheap, spirit dear, and charcoal often impossible to be procured. Hence in different localities, chemists are compelled to choose different descriptions of fuel in virtue of the necessities of their position. Even in the same town, in Scotland, differences arise accidentally. A student in Glasgow, for example, has, in a chemical laboratory, complete command of gas and of coke furnaces. But in his lodgings, if he wish to pursue there the study of qualitative analysis, he is compelled in most cases to use spirit alone. For these reasons, I have made it a rule, in choosing examples by which to illustrate practically various facts and chemical principles, to take such as appeared to me to present upon the whole fewest difficulties to students, not provided with regular laboratory accommodations. I have accordingly generally recommended the use of the spirit lamp, as being readily procured and readily managed—and for very high temperatures I have recommended the argand spirit lamp, where it is applicable, and in other cases, the blowpipe. The use of the latter instrument I shall explain in a separate section, to which I earnestly request the reader's attention.

SUPPORTS FOR APPARATUS.

When you begin to think of holding a vessel above, or in, the flame of a spirit lamp, you begin also to think of the means of doing so without burning your fingers. It is by the use of different sorts of supports or holders that this object is gained. We modify these supports according to the size and form of the vessel to be supported, according to the degree of steadiness required, and to the temperature to which the vessel is to be exposed.

SUPPORTS FOR SMALL GLASS VESSELS.

If the instrument to be supported over a lamp is a glass tube, or a small flask, and the time during which it needs to be held is very short, the readiest way, as I have said at page 9, is to hold the open end of the vessel with the thumb and middle finger of the right hand, closing its mouth with the fore-finger of the same hand.

But if the operation is to last some time, or if the gases that may be produced are to be allowed to escape, and in their pas-

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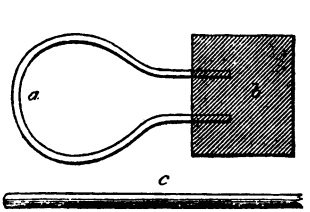
sage forth, to warm the mouth of the tube, then it becomes necessary to protect the fingers from the heat by the interposition of a slip of woollen cloth, or of blotting paper, folded several times flat, and of which the ends are twisted together, as shown in the cut, into a sort of handle by which the tube can be held.

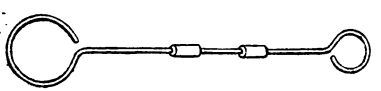
Or you may twist a wire round the tube, and hold the end of the wire in your hand. It is prudent to adopt this plan when an explosion capable of shattering the glass is to be apprehended.

Or, finally, you may take a long flat piece of cork, and adapting one end of it to the mouth of the tube, you may hold the other end by your finger and thumb. This method answers very well in cases of sublimation in small tubes, where it is sometimes desirable to have the whole of the inside of the tube visible at once.

If the object in view is to expose a watch glass, or a small capsule, for a short time to the heat produced by the flame of a spirit lamp, you may employ the instrument figured in the margin. It consists of a piece of iron wire 6 inches long, and as thick as the straight wire *c*, bent into the form of a circle *a*, and having both ends inserted into *b*, a cube of cork of 1 or 1½ inch in diameter.



A modification of this simple apparatus, and which answers very well for supporting small cups and crucibles in the flame of a spirit lamp, consists of an iron wire, bent into a ring at each end; one of them about two-thirds of an inch, and the other 1¼ inch in diameter; with a straight portion seven inches long between them. Upon this straight portion you place, previous to the bending of one of the rings, two long bottle corks, which form, when pushed together, a handle to protect the hand from the hot metal.



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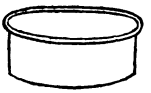
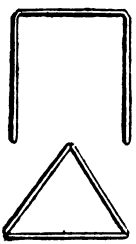
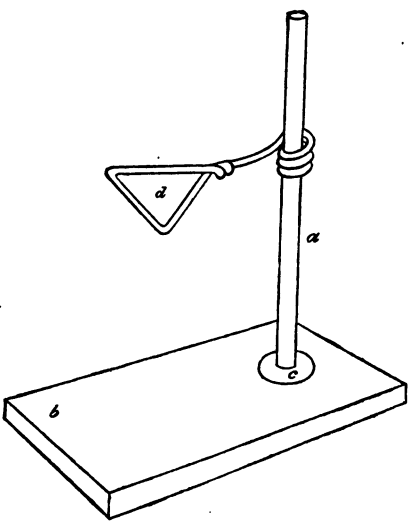


Retorts and flasks can be supported on the table, in an upright position, by means of rings of straw, or by rings of tin plate, either simply japanned, or twisted round with straw, string, or worsted.

A supporter for retorts, flasks, and basins over a lamp may be constructed of stout iron wire as follows: You take three pieces of iron wire, one-eighth of an inch thick, and about fourteen inches long, and bend each piece into the form of the adjoining upper figure. You then bind them together, by two and two, at the angles, with thin wire; by this means you produce a frame, the upper surface of which is a triangle, like the lower adjoining figure. The glass vessel to be heated is placed upon this triangle, and the spirit lamp is placed below it, between the legs of the stand. This kind of support can be readily prepared and is both economical and portable.



For this and other supports, that are constructed in such a manner that the resting-place of the vessel to be heated is at a *fixed height* above the table, it is necessary to be provided with the means of raising or depressing the lamp, which is to be placed below the vessel to afford the required heat. The simplest contrivance of this sort, consists of a series of blocks of wood, four inches square, and varying in thickness as follows:—4, 2, 1, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$ inch. The price of such a set of six blocks is 1s. 6d.



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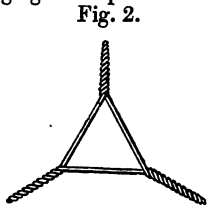
RETORT HOLDER, OR TRIANGLE SUPPORT.

When you wish to support a flask or a retort for a considerable time over a lamp, you must, in cases where the cylinder (page 24) is not available, employ a piece of apparatus generally termed a *retort stand*. This is represented on the preceding page. It consists of a brass or iron rod, *a*, one-third of an inch thick, and eighteen inches long, screwed into the end of a piece of board, *b*, five inches wide, and nine inches long; or else screwed into a female screw, *c*, sunk into the board. The rod must be furnished with a horizontal arm, having a ring or a triangle at one end, *d*, and a coil or worm at the other. This arm must be made of iron or brass wire about one-eighth of an inch thick. The triangle should measure three inches each side. You form the worm by fixing the large rod and the end of the wire in a vice, and then coiling the wire four or five times round the large rod. Such an arm moves loosely up and down the rod, but becomes fixed when a weight is placed on the triangle. This triangle can be made to support any sort of apparatus, however small. You have only to lay upon it various sized triangles or trellis work (p. 26.) of fine iron wire.

The following figures represent two ways of bending wire into triangles for this purpose. The second method is the best. Some of these triangles should be made of iron wire, not more than the thirtieth of an inch in thickness. They serve to support crucibles in the flame without carrying off much of the heat.

Fig. 1.

Fig. 2.



It is convenient to have, in addition to the large retort stand described above, one or two others of the same kind, but of the following dimensions:—

Upright rod, 9 inches long, $\frac{1}{8}$ inch diameter.
Foot (of beech), 7 inches long, $2\frac{1}{2}$ inches wide.
Triangle, 2 inches each side, wire $\frac{1}{10}$ inch thick.

This is the sort often referred to in this work as the triangle support for small vessels.

When great weights have to be supported, it is perhaps safer to provide the triangles with screw-nuts, to fasten them more securely against the upright rod, than can be done by the simple pressure of the coil. But in most cases, it is best to support heavy vessels by means of Sefstroem's holder represented at p. 39.

Triangles are preferable to rings for the support of retorts, flasks, and capsules, in consequence of their not so completely *cutting off* the heat from the upper part of the vessels they sup-

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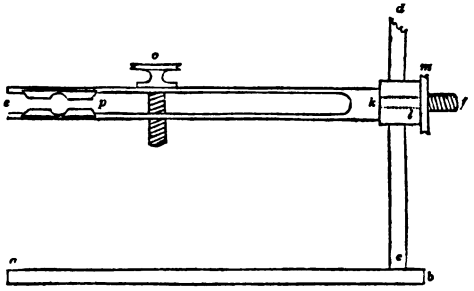
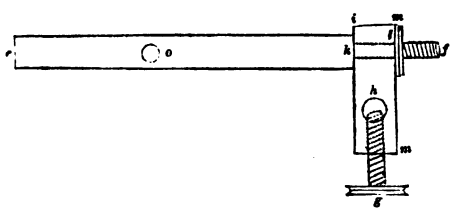
port. A thick ring is a perfect barrier to the upward progress of the flame of a lamp.

GAY LUSSAC'S RETORT HOLDER.

THE following description applies to a retort-holder contrived by GAY LUSSAC. Its object is to support the retort, by grasping its neck, instead of sustaining its body, and so to acquire the power of placing and of retaining the vessel in any desirable position without interfering with the action of the flame upon



the contents of the retort. *a b* is a board, and *c d* a round stick screwed into one end of it. This serves to support a sort of wooden finger and thumb, *e f*, represented in the second figure, as seen from above. *h* is the hole through which the stick *c d* is passed, and *g* the screw by which the parallelopepidon *i m* is fixable at any required height. At *k* is a hole vertical to *k*, through which the peg *f* passes. The end of this peg is cut into a screw, and provided with a nut *m*. It follows from this arrangement, that the fork or finger and thumb *e f* can be turned on its axis, and be fixed by the screw *m* in any given position. In the upper figure the entire apparatus is seen in profile. At *o*, one-third of its length from the end, a hole is bored through both limbs, that in the upper limb being made smooth, while the one in the lower limb is provided with a female screw, and made rather smaller in diameter. Hence when the wooden screw *o* is inserted through both holes, it moves freely in the upper hole, but fixes in the lower. When it is screwed up, therefore, its head forces the two limbs of the fork together, and secures any object that is



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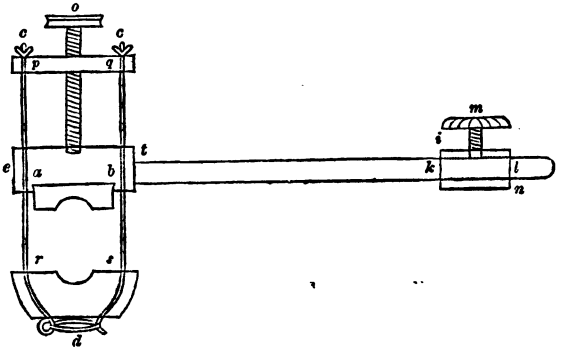
placed *between* them. The end of the apparatus *e p* is armed with two grooved corks let into the wood, and serving to equalize the pressure exerted by the screw *o* upon the necks of retorts, and thus prevent their fracture. It is clear that, by raising or depressing the fork *f*, or by turning it either on its axis *k f*, or round about the rod *c d*, we can command every desirable position and inclination.

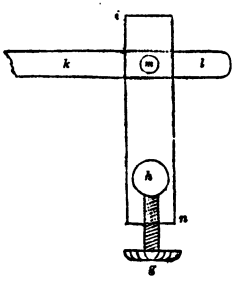
If this instrument is intended to hold large retorts, or for use on a lecture table, the length of *e f* should not be less than 12 or 15 inches. If it is to be used with small apparatus, it need be only 8 inches. The upright rod for the one should be $\frac{3}{4}$ inch thick and 18 inches long, for the other, $\frac{1}{2}$ inch thick and 9 inches long. Neat holders of this description are given in EDE'S *Chemical Laboratories*.

SEFSTROEM'S RETORT HOLDER.

ANOTHER instrument of this kind has been contrived by the Swedish chemist SEFSTROEM, which differs from the preceding in



the construction of the arm only, and not in the upright rod or foot. The parallelopepidon *i m* of the former figure remains also the same in this instrument, in the figure of which it is marked *i n*, as does likewise *g*, the screw for fixing it on the rod *c d*. But instead of the short peg *k f* in the former figure, there is in SEFSTROEM'S holder, a long round peg *t k l*, which can be pushed backwards and forwards in the hole, *k l*, or be fixed at any part of it by the screw *m*. The block *e t* is a parallelopepidon of wood, through the two ends of which pass two strong steel wires, *c s d* and *c r d*, fastened above



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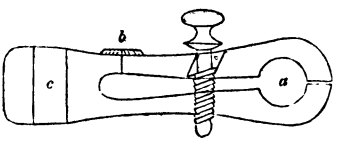
in a block of wood by means of the nuts *c c*, and bent below, so that the one holds a small ring, and the other is bent into a hook to catch the ring. The block *e t* moves freely upon these wires. At *a b* a piece of cork is cemented, and another at *r s*. These are grooved on the sides opposed to each other, so as to form a receptacle for the neck of a retort. The pressure which fixes the retort in its position is communicated by the screw *o*. This apparatus answers very well for the support of large and heavy vessels. It is prepared for sale in Glasgow, at the price of 5*s*. The instrument given for this sum, is handsomely and substantially made, and I can recommend it as a useful piece of apparatus for such operations as distillation, where it is sometimes necessary to connect together several vessels into a mass, the weight of which requires a pretty solid support.

A simple and powerful arm, qualified to hold heavy vessels, may be made on the principle of the common vice. It should be 6 inches long, formed as shown in the figure, and of plane-tree wood. The orifice *a* is intended to grasp the neck of a retort. It is opened or closed, and secured when necessary, by the screw. The hole in which the screw works in the upper limb is bored aslant, so as to permit the screw to remain upright when the jaws of the vice are open. The nut of the screw presses upon a cross peg, which is fixed across the upper part of the hole in the upper limb. A little circle in the figure shows its position. The opening of the vice is provided for by the hinge *b*. The butt-end of the instrument is bored, *c*, for the insertion of the support, either perpendicularly or transversely, according as you destine the vice to hold long objects horizontally or perpendicularly. The fixing of the vice upon the upright support is effected either by the interposition of a bored cork, or by a screw, as are the branches of the retort holders of Guy Lussac and Sefstroem.



It is scarcely necessary to add, that this vice is adapted to hold thin or small objects, when placed between its lips at the extreme end. It is used by Berzelius to support a water bottle in the washing of precipitates.

METALLIC TUBE HOLDER.

A disadvantage attending the use of these wooden retort holders, particularly when made of a small size, is, that the wooden screws, being of small mass, soon *lose their threads*, and will then no longer hold a vessel with safety. To remedy this evil, I have contrived a metallic holder in which there are no screws, but which has, nevertheless, every desirable movement, and which

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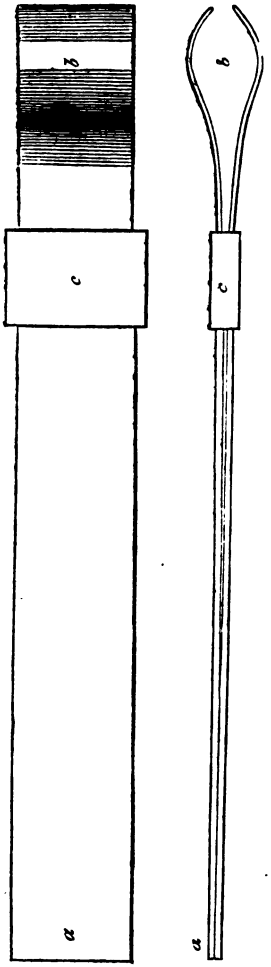
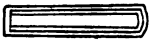
is at once effective, durable, and cheap. It is a modification of an apparatus employed by Professor Graham. The instrument is sold in Glasgow for eightpence, or mounted with a foot and rod, for one shilling.



a b represents a piece of strong tin plate, about 10½ inches long and half an inch wide, bent flat in the middle at *a*, and a little rounded at each end *b*. *c* is a double coil of tin plate, half an inch wide, adjusted to run easily, but not loosely, up and down *a b*. The object in making a double coil, is to give sufficient substance for the fingers to catch hold of readily.



When the coil *c* is moved towards the end *a*, the finger and thumb *b* open by the spring of the metal. If, then, any object is placed in the hollow *b*, such as a glass tube, a blowpipe, or the neck of a small flask or retort, and the coil *c* is brought back towards the end *b*, the pressure it exerts there, fixes the object with sufficient firmness to be held steadily over a lamp. Thus the coil *c* acts the part of the screw *o* in the apparatus previously described. When the vessel to be supported is large or heavy, or of a conical shape, the grasping power of the clasp *b* is much improved by the insertion of a bit of woollen cloth or of thin sheet Indian rubber between the clasp and the vessel.

The instrument in this state can be used instead of the contrivances described at page 35, to support tubes or small flasks over the flame of a lamp.

There remains to be described the substitute in this apparatus for the parallelopepidon *i m* in the former instrument (page 38) which serves the purpose of holding the fork on the upright

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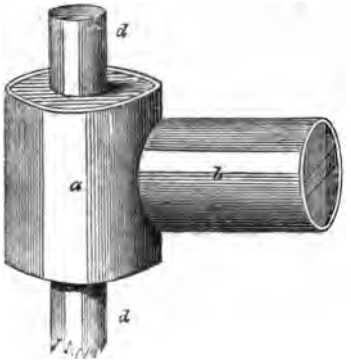
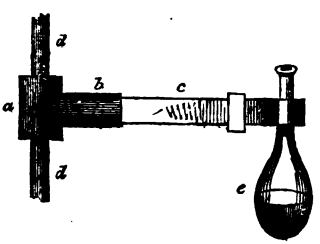


rod, and of turning it on its axis. In the annexed figure, *a* and *b* are two small cylinders of tin plate, represented in their full size. They are each an inch long. The larger is two-thirds of an inch wide, and the latter half an inch wide, or it is exactly so large as to enable the end *a* of the former instrument *to turn round in it.* The smaller cylinder is soldered perpendicular to the larger, and the larger is filled with a cork, having a hole in the centre by which it slides up and down, or turns round about, on the upright rod *d d.* The smaller cylinder is also filled with a cork, or rather with two corks, which have between them a space just large enough to admit the end *a* of the fork *a b*, which must be pushed into the smaller cylinder till it comes into contact with the cylinder *a*. This divided cork is shown at *c*. It must be cemented with wax to the thin slip *a*, but must, with the tin slip, turn freely in the cylinder *b*.

This apparatus is represented in a connected state in the following figure, where *d d* is the upright rod, *a* the tin cylinder that gives the up-and-down and round-about motions, *b* the cylinder which enables the arm of the finger and thumb to turn on its axis, *c* the clasp or finger and thumb, and *e* a flask held by it in a vertical position.



The power which in this apparatus replaces the three screws of Gay Lussac's holder, is the *friction* of the corks in the tin cylinders, on which I find that greater reliance can be placed than upon the wooden screws, while it is a power much more under the control of the operator. *Two* hands are required to manage the screw, when the apparatus is loaded, while *one* is sufficient to twist round the cork.

The rod and foot adapted to support this tube holder are those of the small retort stand depicted at page 36; or, what answers better, a foot of the same kind with a rod of wood instead of the brass rod. The acid vapours produced in the course of experimenting, soon corrode the brass rod so much as to prevent

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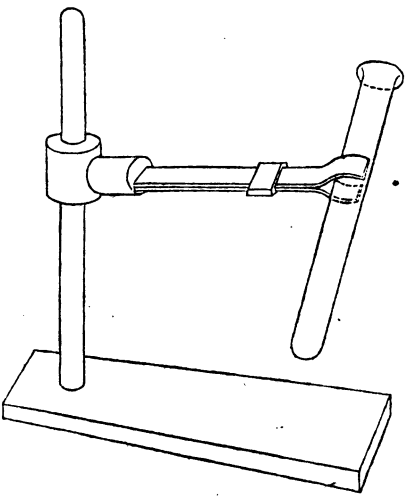
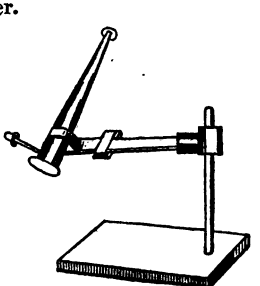
the cork of the tube holder from running up and down with sufficient facility. This is not the case with a wooden rod, which should be about 9 inches long, and two-fifths of an inch in diameter. The cork moves easiest when the rod is greased with tallow. The cork which is fixed upon *c*, and works within *b*, should also be greased.

I subjoin a figure of the tube holder in a complete state, grasping a glass tube. This apparatus is able to support any glass vessel, the neck of which does not exceed an inch in diameter, and the body of which is not larger than is sufficient to contain 3 or 4 ounces of liquid. In cases where the upright rod is too short for the purpose in view, the entire apparatus can be raised above the table by means of the blocks described at page 36.



The following cut shows the method of supporting a blowpipe by this holder.



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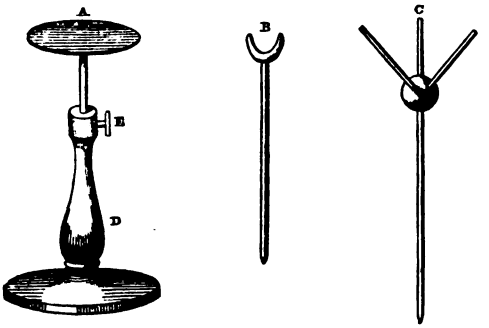

To hold up at varying heights from the table, lamps, receivers, and other apparatus, it is convenient to possess a foot D, with wooden supports such as are represented by A B C, all provided with stalks adapted to the hollow tube of the foot D. These are then fixable at any given height by the screw E.—The flat plate A is intended to hold a lamp, but it can also be used to support a round bottomed vessel, if provided with a straw ring. It is better, however, to support round bottomed vessels, receivers, basins, &c., between the three pegs of C, which hold them more securely.—The crook B is intended to support tubes.

It often happens in the adjustment of complicated sets of apparatus, as for example, of that requisite in the preparation of solutions of gases, that some one particular piece of the apparatus requires to be made to *incline* a little on one side, in order to bring it into a good position in respect to the adjacent pieces. This can generally be effected by *tilting* one side of the vessel that is to be inclined, or one side of the foot of the retort holder on which the vessel rests. To be able to effect this tilting when needful, you should be provided with two pieces of board, each 4 inches square, and wedge-shaped; one of them an inch thick on one side, diminishing to a quarter of an inch on the opposite side, and the second piece, a quarter of an inch on the thickest side, feathering off to nothing.

Various other means of supporting vessels, or of adjusting them to one another, yet remain to be noticed; but they are of less general utility than the foregoing, or they relate to operations which fall to be described in subsequent sections, and which cannot be introduced here without anticipation.

Of all the supports here mentioned, the most useful to a student are the small triangle and rod (page 37) which costs 10d., and the tube-holder (page 41) which costs 1s. These, with the lamp furnace (page 24), are sufficient for many operations. The next most useful supports are the set of blocks at 1s. 6d. (page 36) and the large *Sefstroem's* holder at 5s.

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TESTING.

A *Test*, or a *Re-agent*, is a substance which has the property of producing a particular phenomenon when brought into contact with some other substance, whereby the presence of that other substance is made manifest. The phenomenon produced by the bringing of an unknown substance into contact with a substance of known properties, is called *re-action*, and the known substance that produces the phenomenon, a *re-agent*. Thus infusion of galls *re-acts* upon solutions that contain iron, and produces a black colour. Infusion of galls, therefore, is a *re-agent* that serves to indicate the presence of iron, or, briefly, it is *a Test for* iron—a witness that testifies to the presence of iron. A drop of any acid let fall into a blue solution of litmus changes its colour to red. Litmus, therefore, is a test for acids.

Generally speaking, tests are applied to use in the state of liquids. Any unknown substance that is to be examined is brought into solution by a suitable liquid, and the substances that are to re-act upon it, in order to produce phenomena such as shall lead to its recognition, are also brought into solution. The subsequent and systematic mixture of these solutions, and the examination of the results, constitute what is called *Liquid testing*. In some cases, however, both solid and gaseous substances are employed as tests.

The two phenomena of most universal production in liquid testing, are *change of colour* and *formation of solid matter*. Both of these phenomena are owing to the production in the mixed solutions of new compounds possessed of new properties. The reason why in some cases there is a production of solid matter, and in other cases no such production, is, that sometimes the compounds which are produced are *soluble* in the resulting liquid, and sometimes are *insoluble*. Hence this production of solid matter, or as it is called *precipitation*, depends not merely upon the nature of the substance that is produced, but upon the solvent powers of the liquid in which it originates. Accordingly the *same compound*, produced in one liquid, dissolves, and in another, precipitates. It requires a general acquaintance with the solvent powers of different liquids, and with the properties of a wide range of chemical substances to enable one to interpret aright the indications afforded by the operation of testing.

This information is to be sought for among the characters of chemical bodies, and among the Instructions for Chemical Analysis, presented in another part of this work. I have here only to treat of the proper *application of the tests*, and to describe the apparatus, and explain the terms, which relate to this operation. I shall commence by explaining what is meant by *neutralisation*, and by showing the relations of acids and alcalies to coloured test papers.

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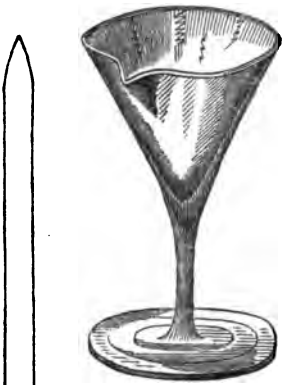
NEUTRALISATION.—*Action of Acids on Vegetable Colours.* [Make these experiments in a glass, such as is shown in the margin, using a stirrer of the annexed size with each glass.]



Mix a little tincture of cabbage with a glass of water, so as to form a clear blue liquor. Drop into the mixture a little sulphuric acid. The colour will then turn red. Every other acid produces the same change.

Make a blue mixture of water and tincture of litmus, and add a few drops of any acid to it. The colour will turn red.

Put a drop of any acid into a glass of water, and dip into the mixture a slip of blue litmus paper. The colour of the paper will be changed to red.

Action of Alcalies on Vegetable Colours.—Into a mixture of water and tincture of cabbage pour a few drops of liquid ammonia, or of a solution of potash. The blue colour of the liquor will change to green. All alcalies produce this change.

Make a yellow liquor by mixing tincture of turmeric with water. Add a little liquid ammonia or solution of potash to this liquor. The colour will become brown.

If you mix water with any alcali, and then dip into it a slip of turmeric paper, its yellow colour will be changed to brown.

Counter Actions.—If you add an alcaline liquor to the tincture of cabbage which has been reddened by an acid, the liquor first regains its blue colour, and finally becomes green. If you add an acid to the tincture of cabbage, which has been rendered green by an alcali, the liquor becomes first blue and finally red.

The reddened litmus paper regains its blue colour in an alcaline solution, and the browned turmeric paper regains its yellow colour in an acid solution.

Try the effect produced on litmus paper and turmeric paper by diluted nitric acid, and dilute solution of caustic potash. Then mix the two diluted liquids together, adding the one to the other gradually, and trying from time to time the action of the mixture on the coloured test papers. You will find a point at which the mixture affects the colour neither of the litmus nor of the turmeric.

When a liquid effects no change in the colour of turmeric and litmus, it is said to be *neutral.* When it turns blue paper red, it is said to be *acid.* When it turns yellow paper brown, it is said to be *alcaline.* When you render an acid liquid alca-

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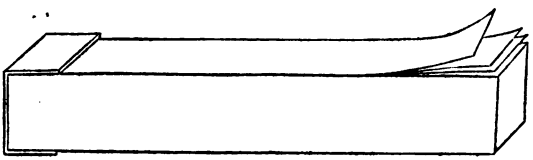
line by adding an *excess* of an alcaline solution to it, you are said to *supersaturate* the liquid. If you then render the supersaturated solution neutral, by adding a certain quantity of acid, you perform what is called *neutralisation*.

In trying the neutrality of a liquid, you may either dip the end of the test paper into the liquid, or draw a line across the slip of test paper with the point of a clean glass rod dipped into the liquid for trial. The latter method is the cleaner of the two.

The preparation of these coloured liquids and of the *test papers* will be fully described in the article on *vegetable colours*, section HYDROGEN, where also will be given an account of the peculiarities of their action with different chemical substances. Each test paper is bound up into a book of the following size, a leaf from which is used for every different experiment. Thick cotton thread dyed with the coloured tests can also be conveniently used in testing.



TESTING.—Generally speaking, a liquid to be tested contains either an acid, an alcali, or a salt of some metal. It should be put into suitable glasses, and the tests added with suitable precautions. Each test, upon being added to the solution of the salt which is to be analysed, either effects no change, or changes its colour, or produces a precipitate, and the precipitate is either white or coloured. The constituents of salts are acted upon differently by different tests, and are consequently arranged in Tables for Testing, in different sections, under the names of the different tests. It is from a comparison of the effects produced by a variety of tests applied to a given saline solution, that an opinion is formed as to the nature of the salt which the solution contains.

There are commonly two sets of tests used in testing. The object of the one set is to detect the *base* or metallic part of the salt; that of the other set to detect its *acid*.

It is necessary to use a very small quantity of the liquid to be tested; if it is scarce, three or four drops will be sufficient; if it is plentiful, as much as fills half an inch of the glass may be taken. When the solution is concentrated, a smaller quantity answers than will fulfil the object when the solution is dilute. The tests must be added in very small quantities. When a test is delicate in its indications, you may dip the end of a clean glass rod into the liquid test, and then stir the liquid in

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the test glass with the wetted end of the rod. When a rod is dipped into oil of vitriol, and then into a clear solution containing a salt of barium, you immediately observe the formation of a white precipitate of sulphate of barytes. If the test to be applied is not delicate in its indications, a more considerable quantity must be applied. Occasionally, it is necessary to add a considerable quantity of the test, in order to re-dissolve the substance precipitated by a small quantity. It is always improper to add a test liquid in large quantity at first; the proper method is to drop it in gradually.

Stirrers are necessary to be provided. Their use is to mix the test with the solution by agitation or stirring. They should be made of strong glass tube, or of round rods, proportioned in length to the glasses they are to be used with, and from one-eighth to one-third of an inch in diameter, according to their length, and to the probable stiffness of the mass of precipitate they may have to stir. Very useful sizes are 3 inches long and $\frac{1}{8}$ inch thick, 6 inches long and $\frac{1}{8}$ inch thick, 9 inches long and $\frac{1}{4}$ inch thick. The ends of the tubes must be closed neatly before the blowpipe. One end should be somewhat pointed, the other round and blunt. The shape is shown at page 46. They must always be made of soft glass, otherwise they scratch and spoil the test glasses with which they are used.

Narrow slips of window glass cannot be substituted for glass rods as stirrers, for their numerous roughnesses and sharp edges make it alike difficult and dangerous to clean them. I cannot conceive why Dr Reid advises students (*Rudiments of Chemistry*, p. 89) to use such troublesome and inefficient rubbish, instead of round stirrers. A regard to economy can be no reason, because the price of the best smooth glass rod is seldom much more than a penny per foot.

With one of these stirrers the solution under process of testing is agitated, after each addition of a drop or two of the test. If no precipitate appears after several additions of the test, the solution is allowed to repose. Precipitates do not appear in some cases, especially where the solution is very dilute, and where the precipitate assumes a crystalline form, until some time has elapsed. Consequently the effect of the test cannot be judged of in an instant. Modifications in the production and properties of precipitates are often produced by heat and light, by the oxygen and carbonic acid of atmospheric air, and by evaporation and crystallisation; all of which acting powers must in certain cases be allowed time for operation. Whenever this occurs, it is proper, as a means of preventing mistake, to affix a bit of gum paper to each glass which is set aside, stating the name of the solution that it contains, and with what re-agent it is mixed. The precautions necessary to be taken, to free the indications of each particular re-agent from ambiguity, will be described in subsequent sections.

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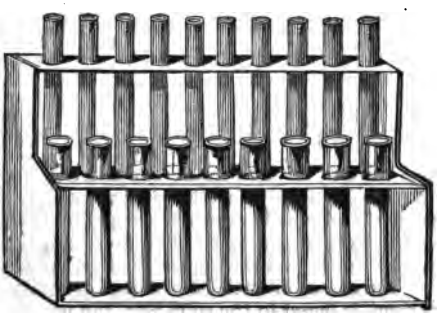
TEST GLASSES.—Very different are the forms that have been recommended as best suited to contain the small portion of a solution which is to be subjected to the action of a reagent. Small cylinders of glass, one inch wide and three inches long, mounted on a short stalk and foot, have been much used for this purpose. But this form of test glass is objectionable, as being too capacious at the bottom, and therefore not adapted to the testing of small quantities. Glasses of this shape, but of 8 or 10 inches in height, and 2½ inches in width, are still advantageously used by lecturers for performing class experiments on precipitation, where the changes are intended to be seen by a distant or numerous audience.

HENRY ROSE, in his *Analytical Chemistry*, recommends as the most useful vessels for testing, straight tubes of white glass, such as the one pictured, *c*, on page 8. He notices also that conical wine glasses can be used for testing, but he decides in favour of the tubes. His reason for the preference is, that in such vessels the liquid can, if necessary, be heated over the flame of a spirit lamp, which is not the case with glasses that stand upon a foot, while the heating is in many cases of qualitative analysis a practice of great utility. The best length for such tubes is six inches, the width two-thirds of an inch. A single tube of this kind can be supported by a large perforated cork. But as in general a great number of tubes are employed in testing a solution, it is proper, according to ROSE, to be provided with a small frame which can hold nineteen of such tubes in two rows, the glasses in the upper row being rather smaller than those in the under row, and the largest being of the size above-mentioned, namely, six inches long, and two thirds of an inch wide. Such a frame is figured below.



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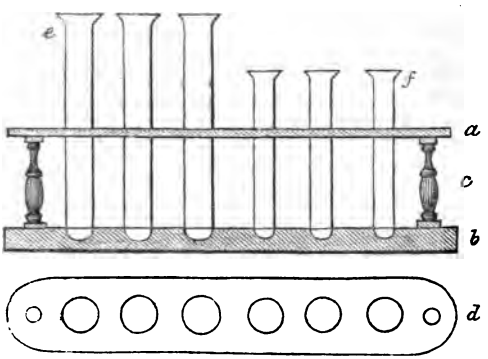
It is, perhaps, more convenient, where tubes of this kind are used, to support them, not in a single frame that holds so large a number, but in several small frames of 4, 5, or 8 holes each. This I recommend particularly where students are to be exercised in systematic testing according to methods laid down in Tables of Tests. For example, where Leading or Indicating Tests are arranged in sets of 4, 5, or 8, as they are in another part of this work, it is advisable to have the test tubes also in sets of 4, 5, and 8 to correspond. Such a system will be found to save considerable time where a number of students are to work on the same class of subjects. And as the arrangement of the tubes in the frame serves to indicate the order in which the tests are added, there is a security against mistaking the results of the operations. For example, if the first test in the table of tests is carbonate of soda, and if 5 or 6 tests have been added to as many different tubes, the first tube in the frame, and never any other, should exhibit the result produced by the carbonate of soda. It is a good plan to label the frame in front of the holes with the names of the tests that are to be used with the tubes.

A tube frame of the sort here referred to, is represented in the following cut, where *a* and *d* represent a slip of wood (plane-tree answers best) 1¼ inch wide, and 6 or 8 inches long, according to the number of holes to be made in it for the tubes. *b* is



the foot, one-third of an inch thick, one and a half inch broad, and half an inch longer than the upper board *a*. *c* are two small turned pillars which support the perforated board, one and a half inch above the foot. The holes are made a little wider than the tubes, and are a quarter of an inch apart. Exactly under the centre of each hole a conical cavity, a quarter of an inch deep, is bored in the solid foot, the use of which is to receive the lower extremities of the tubes, and keep them steady.

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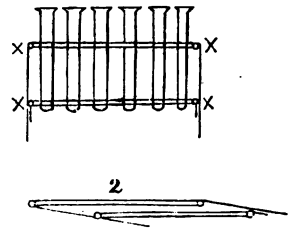
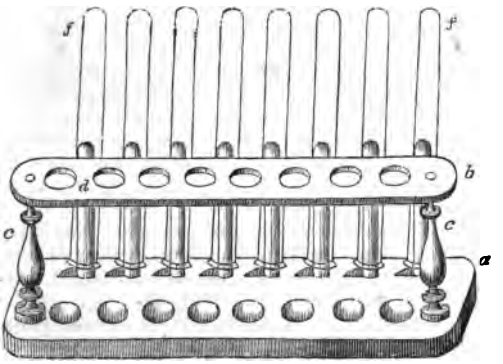
From *e* to *f* is represented a set of tubes placed in the frame ready for use. The price of such a frame is 8d.

The next figure represents a tube frame adapted to form part of the portable laboratory of a travelling mineralogist. It is formed of tin plate, and japanned. The platform x x is perforated for the reception of 6 tubes of half inch width. The holes are one-eighth of an inch apart. The platform is one inch wide and 4½ inches long. The holes in the lower platform are a little smaller than those in the upper, so that, though the ends of the tubes enter them, the tubes cannot pass through. The apparatus has therefore no need of a base. The supports at the ends are 2 inches high, 1 inch wide at the top, and widen out to 1½ inch at the bottom. The sides and platforms are fastened together by 4 hinges at x x x x. When not in use, the frame can be shut flat, as shown at 2, in which form it packs into small space. The tubes are carried in a little box.



There is, however, an inconvenience attending the use of tube frames of this description, which is not dwelt upon in chemical books, but which proves to be annoying in practice. This inconvenience arises from the circumstance that the tubes, standing always ready for use, with their open mouths uppermost, are commonly, when required for testing, found to be full of dust, and to require cleaning. After many attempts to find a remedy for this evil, I succeeded by means of a tube frame of the following construction:—



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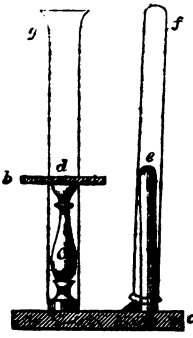
a represents a board 10½ inches long, 3¼ inches wide, and ½ inch thick. *b* is a board, 9½ inches long, 1⅜ inch wide, and one-eighth inch thick, supported over the first board by two turned pillars *c c*, three inches high. The position of the small board is not over the centre of the large board, but on one side, as shown by the annexed figure, which is an *end view* of the apparatus. The small board is perforated with 8 holes *(d)*, each seven-tenths of an inch in diameter, and three-tenths of an inch apart. Exactly under each of these holes, there is in the large board a cavity, six-tenths of an inch wide at the top, and three-tenths deep. An inch distant from each cavity, proceeding towards the opposite edge of the large board, and at half an inch distance from the edge of the board there is fixed an upright peg, as shown in both figures, and marked *e* in that above. In all there are 8 pegs, each 3 inches long and three-eighths of an inch in diameter. The whole apparatus is constructed of plane-tree wood.



Eight test tube of the largest size, namely, 6 inches long and ⅝ inch wide, are used with this test stand. When not in use, the tubes, previously cleaned, are inverted over the pegs, as shown at *f* in both figures. When required for testing, they are turned over as at *g*, and supported in the holes *d*.

Against the foot of the pegs, on the inner side, and extending the whole length of the row, is nailed a feather-edged slip of wood, ¼ inch wide, and ⅛ inch high at the side where it touches the pegs. The use of this ridge is to keep open the mouth of the tubes, so that when after use they are washed and placed upon the pegs, the water may drain out and the tubes become dry. The position of this ridge, and the manner in which it elevates the tubes a little above the foot board, and tilts them a little on one side, is represented in the figure above, where a cross section of the feather-edged slip of wood appears on the left side of the peg. This ridge is omitted in the front view of the apparatus, where every peg is represented as furnished with a separate support for each tube, whereas it should have shown a single slip running along the front of the entire range of pegs.

This apparatus fully answers its intended purpose, and greatly facilitates the use of tubes as test glasses. The price at which it is sold in Glasgow is 1s. 6d., or fitted with tubes, from 3s. to 4s.

Another German chemist, WACKENRODER, recommends test glasses of a very long conical shape, like the figure in the margin, or like champaign or ale glasses. Of this form of vessel he describes two sizes as most useful: the

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smaller 1 inch wide at the mouth, $2\frac{1}{2}$ inches deep within, and 4 inches long including the foot; the larger $1\frac{3}{4}$ inch wide at the mouth, $3\frac{1}{2}$ inches deep within, and $5\frac{1}{2}$ inches long, inclusive of the foot. He admits the necessity of warming the solutions in some cases of testing, but states that it is better to transfer a solution that requires heating, into a small flask, than to use tubes in all cases of testing.

Glasses of the long narrow form last described, may be applicable in two cases of testing:—1. When the solutions are small in quantity, but concentrated. 2. When the precipitant is to be added in large quantity to re-dissolve a precipitate. The acute angle of the base makes them useful in the first case. The large capacity of the principal glass makes it handy in the second case. But there is in general testing, a case of frequent occurrence which these glasses do not seem well adapted to answer: it is where, in consequence of the extreme dilution of the solution, the colour or the precipitate produced by the test is too slight to be readily seen except in a pretty large *mass* of the mixture. Now this *mass* you cannot have in such narrow glasses. Unless you fill them, you can have no body of liquor to look through; and though you may sometimes discover a tint by looking *down* into the liquor, such a method of observing is not a good one. This defect is obviated in the glass figured in the margin, which resembles the test glasses used in the laboratory of Professor Clark of Aberdeen. The height of this glass is $3\frac{3}{4}$ inches. The width of the mouth is two inches, and the perpendicular depth of the cone is two inches. The width therefore in proportion to the depth is greater than that of wine-glasses or any ordinary test-glasses. It is in fact made so, in order to get that *broad mass* of liquor to look through, which most readily shows the slight changes of colour produced by re-agents in very dilute solutions. The capacity of this glass is one ounce. The length of the stalk nearly $1\frac{1}{2}$ inch. The width of the foot 2 inches. It is provided with a spout for the convenience of pouring liquids into a small flask, when it is necessary to warm them.

I have yet to enumerate such of the qualities of a good conical test glass as are independent of the considerations noticed above. It should be of very clear and colourless glass, worked smooth, and not misshapen, streaked, or blebby. The stalk should be thin and without ornament, and the sides of the glass thin where the apex of the cone joins the stem. If, on the contrary, the glass is thick at this point, and the transition clumsy, it

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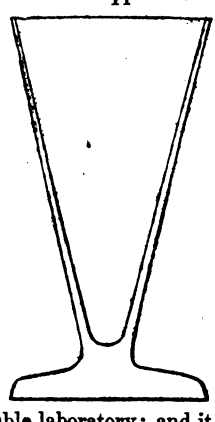
will be impossible to test small quantities in it with any reasonable chance of *seeing* the results. The point of the cone within should be small, round and smooth. It must not run down into a capillary point, otherwise it cannot be easily cleaned, nor must it rise up into a bump, nor yet be spread out into a flat plain; all of which defects are more common in bad glasses than unobservant people imagine.

Test glasses of this kind are the more useful, the more delicately they are formed; but the employment of well made glasses in a laboratory meets with a serious obstruction in the astonishing clumsiness of some persons. I have seen students of chemistry handle test glasses with less care than a carman does a dram glass. Some of them appeared to feel pleasure in applying the lever power of their heavy fists to the two ends of the glass, and twisting it in two at the shank. They did this under pretence of *wiping* them. Experimenters of this sort ought to be designated in every laboratory as the "awkward squad." I was once told by a Professor, that his practical students had broken six dozen of test glasses in a single season. He told me at the same time that he never had had so little reason to be gratified by the progress in science of his class. This proves very clearly that test glasses are never broken in large quantities but by stupid people. It would be proper to dismiss students of this kind from a laboratory on the same ground that incurable patients are dismissed from an hospital—to make room for others that are not incapable of improvement.

For the guidance of such as do not intend to join the "awkward squad," I may say, that in wiping a test glass with a cloth, both hands are to be at once applied to the cone or to the foot, and *never* applied one to each end of the glass. While you wipe the interior of the glass, your left hand should hold the outer part of the cone. While you wipe one side of the foot, your left hand should hold the opposite side, &c.



Another form of the conical test glass is represented in its full size and proportions in the adjoining section. The re-actions that take place in this glass can be readily seen, though not so well as in the glass previously described. It is of a handy size, and is very easily cleaned by the finger or thumb covered with a cloth. It is very strong, and not easily twisted off the shank. In the filtration of small quantities, it can support a paper filter without a funnel. It packs in small compass if wanted for a portable laboratory; and it can be made to sell at a low price.

Each of these test glasses should be provided with a round

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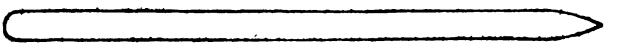
stirrer, as described at page 48, made of glass rod, $\frac{1}{8}$ of an inch thick, and 3 inches long.



The best method of mixing fluids in test tubes is, generally speaking, that of closing the tube with the forefinger and then giving it a shake. A cleaner but less effectual mode of agitation consists in stirring with a glass rod.

When extremely small portions of a liquid are to be tested, it is sometimes useful to employ flat plates of window glass. The unknown liquid is applied to the glass in drops by means of a glass rod, and the test is added to it in the same manner. Watch glasses, however, answer better than flat glass for minute testing, and they answer better in proportion as they are smaller and more concave. The reason is, that slight precipitates produced on a flat surface spread out so as to become invisible. This greatly limits the use of flat glass. The evil can be partially, but only partially, remedied by the employment of plates of coloured glass—dark green, blue, or brown. A great, and, as I conceive, an exaggerated degree of importance has, nevertheless, been recently ascribed to the use of flat glass in testing, by Dr Reid of Edinburgh. In a few experiments of *demonstration*, where the teacher has liberty to choose the most striking re-actions, and can work with solutions in a state of concentration, the flat glass may, indeed, exhibit sufficiently good results. But in experiments of *research*, where the operator has often to employ very dilute solutions, and where the changes produced by the tests are sometimes so very slight as to be scarcely visible in the best conical glasses, it is a farce to speak of testing on flat glass.

Re-agents.—It is necessary, for experiments of research, where particular nicety is required, to be furnished with re-agents in the very greatest possible degree of purity; but, for many ordinary purposes, the different substances may be made use of in the degree of purity at which they are sold by respectable druggists.

Solutions of salts must be prepared by dissolving the solid substances in distilled water.

You ought never to keep a large quantity of a test in solution, and never prepare a solution which is liable to spontaneous decomposition, until the moment when you are going to employ it. In general, your saline solutions should be nearly concentrated; that is to say, the water should contain nearly as much of the salt as it is capable of dissolving. If at any time you require a dilute solution, for accurate neutralisation or other purpose, you mix a little of the concentrated solution with distilled water in a separate glass. The proper strength of test solutions, intended for the production of particular phenomena, is generally stated in this work.

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Your test solutions must always be transparent and free from deposit. In preparing them, you put the salt and water into a glass, and stir them until the water leaves no portion of the salt undissolved, or warm the mixture in a small flask placed on the hot plate or trellis of the lamp furnace. You then pour the solution through a paper filter held in a funnel (see article FILTRATION,) and receive it in a bottle which must be previously placed below the neck of the funnel.

Many crystallised salts can be partially freed from their impurities, by re-crystallisation. You dissolve the crystals in distilled water, filter the solution through paper, and evaporate it in a porcelain basin, placed over the lamp furnace, until its surface exhibits a species of film. You then set the solution aside on a cushion to crystallise, and when it is cold, you separate the crystals from the mother-liquor, which, if small in quantity, and not very valuable, is thrown away; but if of considerable bulk, is again evaporated, and set aside to produce a second crop of crystals. These, however, are nearly in all cases, less pure than the crystals first produced.

BOTTLES FOR RE-AGENTS.—Liquids of all kinds must be preserved in glass bottles provided with glass stoppers; the use of corks is inadmissable. The bottles and stoppers must fit well to each other, otherwise something may get into or get out of the bottle, and in either case spoil the re-agent. Thus, sulphuric acid may attract water from the atmosphere, or liquid ammonia may exhale ammoniacal gas.

The bottles should be of a cylindrical form, short and broad. The neck should not join the body abruptly, producing angles of this sort, ⌊, but should be shaped according to the annexed figure, otherwise the liquid they contain does not pour out well. The rim round the neck should also be thin, flat and uniform, otherwise it is impossible to pour or drop out the liquid without letting some of it run down on the outside. Bottles containing volatile acids generally acquire an external coating of crystalline ammoniacal salt, which makes them unpleasant to handle, particularly when this coating is mixed with a deposition of dust and soot. It is easy to prevent this by providing each bottle with a glass cover—a little bell glass, or a short bottle sufficiently wide to go over the neck and stopper, and to rest on the shoulder of the bottle. Such a cover is exhibited in the cut. Bottles are sometimes made with covers of this kind adjusted to them by grinding. These, however, do not answer the purpose, because the rim of the bottle is removed by the grinding, and the bottle

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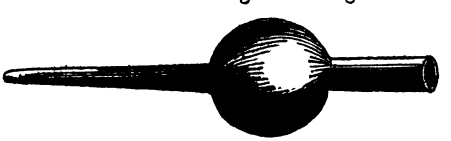
is no longer adapted for pouring from. It is, besides, unnecessary that these covers should fit air tight.

The size of test bottles must be regulated by particular circumstances. A set for a student who works alone, and on small quantities, and a set for use in a laboratory, where many persons are actively engaged, ought necessarily to be of very different magnitude. All that it seems needful to say under this head, is, that bottles smaller or larger may be taken for each re-agent, according to its more or less frequent use. *Distilled water*, being used in larger quantities than any other liquid, may be kept in large vessels. Green wine bottles may suit the purpose of a student. *Spirit of wine* for feeding lamps may be kept in a similar bottle. Oil of vitriol, nitric acid, muriatic acid, liquid ammonia, and caustic potash in solution, may be provided with the largest size glass-stoppered bottles, which for a student's use may be of 4 ounces capacity. Bottles for these five liquids may have the name painted in enamel; such bottles cost 3s. each. Next to these, the tests used in greatest quantity are those which head the columns in the tables of indicating tests. These may be put into bottles of two or three ounces capacity; while other tests, of less frequent use, may be contained in sufficient quantity in ounce bottles.

TRANSVASING OF TESTS.—The method of pouring from a bottle is this. You turn up the bottle and wet the stopper. You draw with the stopper a wet line from the orifice of the bottle to the extremity of its rim. Against the point of this wet line you hold the stopper in a perpendicular position over the vessel in which the test is required. The bottle is then raised to a horizontal position, and the test runs along the wet line, and down the stopper into its destined recipient.

But it is often necessary to use so small a quantity of the test, that it is nearly impossible to transvase it in this manner. You may succeed sometimes in applying a single drop by pouring, but you cannot always do so, and it is better to avoid accidents which *can* occur, and which in some cases prove troublesome. For this purpose you employ a little instrument of glass named a *sucker* or a *dropping tube*. It consists of a glass tube, having a bulb in the middle, and one end drawn out to a point. This instrument should be twice as large as the figure. You put the



narrow point into the liquid, apply your mouth to the upper end, and suck the liquid into the bulb; you then close the orifice of the tube with your tongue, remove the point of the tube into

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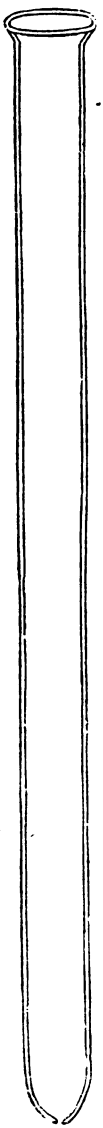


another vessel, and then, by opening the upper end of the tube, permit the liquid to drop out. You must take particular care not to suck the liquor into your mouth, because, if it happen to be oil of vitriol or caustic potash, you may find the taste to be *unpleasant*.

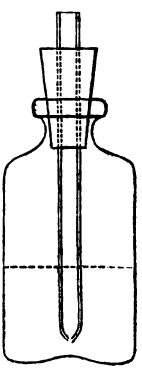
Tubes of this kind are commonly made by the glass blowers too narrow in the beak—too capillary. The effect of this is to produce a degree of friction which makes it troublesome to get the liquid into, and out of, the tube. I find it better in most cases to employ in the removal of tests, and other small quantities of fluid, a tube of the form and size of the figure in the margin.

A narrower tube acts too much by capillary attraction, and does not answer the purpose so well. The point should be merely a little contracted, and not drawn out into a capillary tube.

In using such a tube in testing, it is seldom necessary to suck with the mouth. On dipping the tube into the test a portion enters, more or less of it according to the depth of the dip. As much as may be required is allowed to enter, and is retained by applying the finger to the top of the tube—and just as much as may be wished is allowed to drop into the solution under examination, by a partial or complete removal of the finger.

A modification of this method of applying tests by dropping tubes, may be advantageously employed where a large number of students in a class are furnished with solutions for analysis, and are all to apply the same tests to their solutions.

Two ounce bottles should be provided with large and good corks, perforated and fitted with pieces of straight glass tube of this width:



and so long as to rise half an inch above the cork, and to descend nearly to the bottom of the bottles. The lower end of the tubes may be a little contracted. The tests are to be put into these bottles, and the tubes used to remove them as required. The cork must stand so high above the

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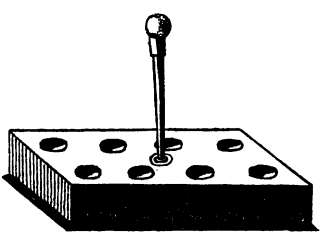
bottle as to be easily caught by the thumb and middle finger of the right hand, while the forefinger is left at liberty to close or open the upper end of the tube, as may be required. The tests are under complete control in this apparatus, so that any quantity which an experiment may demand can be administered with facility. When a very small quantity of the re-agent is required, you lift the tube without closing its upper end. It then acts like a rod and takes up only a drop or two. When you want a larger quantity, you lift the tube out of the liquid, close the upper end by your forefinger, plunge the closed tube into the liquid, and remove your finger. The air in the bottle then presses the liquid up the tube considerably higher than the level in the bottle.

Of course these bottles cannot be used for the conservation of solutions that spoil on exposure to atmospheric air. They are recommended for no such purpose, but for the saving of time in cases where students in *large classes* may be engaged in chemical analysis. The operation of atmospheric air upon the solutions can nevertheless be partially hindered by closing the upper end of the tubes with small corks, when they are not in use.

The number of bottles to be fitted up in this manner for the use of a class, must be regulated by the number of tests required for the purpose in view. Where testing, according to "Tables of Tests," is practised, there must be a bottle for every re-agent which is embraced in the Tables. There will, therefore, be a correspondence between the number of test bottles and the number of test glasses to be provided, and the same motive which has induced me to recommend the frames for test tubes to be made with exactly so many holes as there are tests named in the Tables, induces me also to recommend the preparation of a frame adapted to hold the requisite number of test bottles. Nothing answers better for this purpose than an imitation of the domestic cruet stand, which may be made of a piece of board an inch thick,



pierced with the proper number of holes, of a size adapted to hold the bottles, and bottomed with a thin slip of wood, to keep the bottles from falling through. A wooden rod, half an inch thick, and 8 inches long, screwed into the middle of the board, serves as a handle. A glance at a test stand of this sort, previous to the commencement of a lesson, shows the teacher whether the tests which he purposes to use are all at hand, ready to be applied when requisite.

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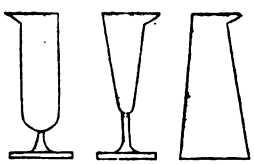
PRECIPITATION.

When two limpid solutions are mingled together, and chemical action is excited, the whole mixture often becomes turbid, and a solid powder, in a state of extreme division, falls to the bottom of the vessel. This powder is called a *precipitate*, the agent employed expressly to produce it, is called a *precipitant*, and the operation which causes its production is called *precipitation*.

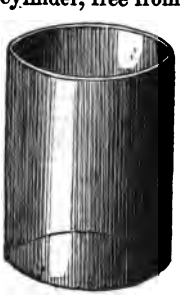
Precipitation is extensively employed in analytical chemistry. In qualitative analysis it is used to demonstrate the presence of certain bodies in solution; and in quantitative analysis it is employed to separate the bodies contained in a solution from one another.

The vessels best adapted for precipitation in qualitative analysis have been already described. (Page 49—55.)

In quantitative analysis, where the precipitates are often of considerable bulk, the best vessels for precipitation are plain cylindrical glasses, such as the confectioners' glass. You may also use vessels like those figured in the margin. They should be of various sizes. It is useful to have a few with the edges ground smooth on a stone. These can be closed air-tight by the application of a piece of ground plate-glass, which is very necessary in certain operations, where the exclusion of atmospheric air is indispensable to the success of the operation.



The confectioners' glass above spoken of, is a simple glass cylinder, free from any kind of ornament. Common tumblers frequently answer for precipitation, but these vessels, which are taller than tumblers and of thinner glass, are preferable. The name here given is that by which they are known in the glass houses. Tumblers are generally too thick at the bottom, and on this account are liable to break when suddenly heated. The annexed cut exhibits the form of the confectioners' glass, but is drawn too wide in proportion to its usual height. The student should be provided with glasses of this shape, capable of holding from a quart down to an ounce. Those which contain two ounces are very useful vessels, as also are those which are capable of holding half a pint. Plain cylinders of this sort are also useful in experimenting with gases, and under the head of "Management of Gases," I shall describe a cheap set of small cylinders, equally adapted for use in precipitation.



Of the three jars figured in outline above, the first, marked 1,

is chiefly used on the lecture table in consequence of the elegance of its shape. It has no quality which facilitates precipitation, and, indeed, its shank and foot are objectionable, as also is all manner of fluting or ornamenting. The second jar (2) is of the shape that facilitates testing on small quantities, but which hinders precipitation, or rather prevents the deposition of precipitates. The third figure (3) represents a form of vessel, better adapted than any of the others for promoting the separation of precipitates from the liquid in which they are produced. This variety of the jar is commonly called Phillips's precipitating glass. Another representation of this jar is given under the head of "FILTRATION," page 71.

Precipitation is sometimes promoted by the presence of alcali or acid in excess. This depends upon the properties of the particular substances which are operated upon. It is in general promoted by agitation, and still more by heat. Precipitation effected in hot solutions gives a coarser powder than that effected in cold solutions, and one which, consequently, is less liable to go through the filtering paper with the liquid. When the application of heat is absolutely necessary, the operation is sometimes best performed in a porcelain or platinum capsule, or in a Florence flask. Occasionally, the solution is first heated, and then mixed with the precipitant. In other cases, the solution is warmed after the precipitant is added: this is done to make the precipitate fall down properly, and become fit for filtration. ROSE, in his "*Manual of Analytical Chemistry*," describes particularly the cases in which the one or the other of the above methods is to be followed. The presence of vegetable matter in metallic solutions often hinder the formation of precipitates which would otherwise be produced. For precise information on this point, I refer you to ROSE's book, cited above.

If you have a substance in solution, and wish to precipitate it entirely, you may proceed as follows:—Add a small quantity of the precipitant, mix it well with the solution by stirring it with a glass rod, and then allow the whole to settle. As soon as the upper part of the solution has become clear, add a single drop of the precipitant. If this causes a troubling, add a little more of it. Stir the whole well together, allow it to settle again, and then test it afresh with another drop of the precipitant. Proceed thus until the addition of a single drop of the precipitant causes no opalescence in the supernatant liquid. Towards the end of the operation, the precipitant should be in a dilute state, provided it be of importance that no excess of it should be added to the solution. It is extremely difficult to hit the exact point of neutralisation—to add precisely enough of the precipitant, without adding too much. In general, precipitation is most completely effected when a slight excess of the precipitant is added to the solution; though the effect sometimes produced by adding an excess of the precipitant is the re-solution of the precipitate. When, however, the precipitant is cheap, does no harm to the

precipitate, and is not injurious to the resulting solution, it is advisable, rather to effect the precipitation by adding an excess, than to lose time by delicately attempting to effect an exact neutralisation.

To provide against the necessity of transferring a solution from a jar in which it may happen to be held into another vessel for the mere purpose of heating it, by which transferring a chance of losing a portion is introduced, the German chemists use a vessel that is adapted not merely for holding a cold solution, but also for heating it in. The form is represented in the margin. It is a cylinder of the proportions of the confectioners' glass, but made of very thin glass, both sides and bottom, and having the upper edge curved outwards. The thinness of the glass enables it to stand considerable and very sudden changes of heat without cracking. The form of the mouth qualifies it for pouring without loss. When a solution is to be warmed, the glass is placed either upon the sand bath, or the hot iron-plate of the lamp furnace.

Glasses of this description (*Beaker glasses*), made of hard white glass, are now imported from Bohemia, and may be purchased in Glasgow of the following dimensions.

The measurement is taken across the centre of each vessel:—

No. 1—3 by 1½ inches	No. 6—6 by 3½ inches
2—3½ ,, 2 ——	7—7 ,, 4 ——
3—4 ,, 2½ ——	8—8 ,, 4½ ——
4—5 ,, 2½ ——	9—9 ,, 5 ——
5—5½ ,, 3 ——	

The price of the nest of 9 Jars.—No. 1 to 9, is 15s.
5 Jars.—No. 1 to 5, is 5s.
3 Jars.—No. 1 to 3, is 2s. 6d.

When English glass makers can be persuaded to make vessels of this kind, or rather when the British government pleases to permit the manufacture of chemical vessels in Britain, they may become cheaper. The freight of these vessels from Bohemia, and the enormously high English custom house duties constitute a chief part of the price above-named. I have a quantity of these glasses now making in Scotland of flint glass, but I am afraid that the nature of that material will not allow it to be blown sufficiently thin.

Berzelius uses for precipitation, as well glasses of this sort, as of a sort nearly the same as this, but blown wider at the bottom than above, so as, in some degree, to resemble the precipitating jars recommended by Mr Phillips. Jars of this shape are much higher in price than the jars which are widest at the upper part; because, as they do not *nest* (pack one within another), they cost more for carriage, breakage, warehouse-room, &c., than jars of the common kind. It is this circumstance, probably, which prevents their general adoption.

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Since page 60 was printed, I have received the plain cylinders alluded to at the foot of that page. The sizes and prices of these are as follows:—

No. 1—2 by 1½ inches, price 3d.
2—3 „ 1¾ —— —— 6d.
3—4 „ 2 —— —— 7d.
4—5 „ 2½ —— —— 8d.
The 4 cylinders in a nest, price 2s.

These cylinders are not only useful to students, but are well adapted for many analytical operations that are practised in the laboratories of manufacturing chemists.

EXERCISES AND CLASS EXPERIMENTS.

CHEMICAL MIRACLE! *Two limpid liquors converted by mixture into a solid mass.*—1. If a saturated solution of chloride of calcium be mixed with a saturated solution of carbonate of potash, both of which are transparent liquids, the result is the formation of an opaque and almost solid mass. Mutual decomposition of the salts takes place—chloride of potassium and carbonate of lime are formed; and the latter, being a bulky solid, absorbs the whole of the water of solution, and thus produces a degree of solidity.

2. Drop sulphuric acid into a saturated solution of chloride of calcium; in this case also an opaque mass is produced. The chloride is decomposed, and sulphate of lime, a highly insoluble salt, is formed.

3. Pour a saturated solution of caustic potash into a saturated solution of sulphate of magnesia (Epsom salt). A nearly solid mass is again produced. The sulphuric acid leaves the magnesia (which then combines with water and is precipitated in the form of a white powder) in order to combine with the potash.

4. If a little nitric acid be added to the product of *process* 1, the solid mass will be converted into a transparent liquid; the insoluble carbonate of lime being converted into the soluble nitrate of lime.

5. The precipitates afforded by the foregoing operations, should be separated from the liquids in which they are formed, by the methods to be detailed in the following articles on "FILTRATION" and "EDULCORATION."

FILTRATION.

WHEN a solution has been prepared for examination, it ought to be perfectly clear. If it appears muddy or troubled, it must be submitted to *filtration*, that is to say, it must be passed through a paper filter, by which means it is separated from the solid matters which make it appear opaque.

In like manner, when a precipitate is to be separated from a solution, we resort to the same process of filtration. In short, this operation is the one which occurs in chemical analysis oftener than any other, and the one upon the proper execution of which, depends a good deal of the success of the analyst. I need scarcely, therefore, make an apology for describing this

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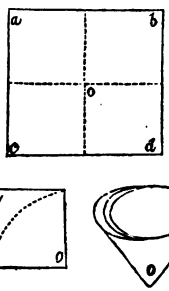
operation at length, or for pointing out with precision the various sources of error, and the means by which they can be obviated.

The operation of filtration consists, generally speaking, in pouring a troubled liquor into a *filter* or cone of porous paper, so arranged as to let the liquor pass in a clear state, and to retain all the solid matter. The things which we have to consider, therefore, are these:—1. The way to fold the paper into a proper form. 2. The shape of the funnel adapted to hold the filter. 3. The means of supporting the funnel with its filter. 4. The way to pour the whole mixture into the filter, and to collect all the clear liquor which runs through it, and all the solid precipitate, without loss. 5. The quality of the paper fit to be made use of for filters.

HOW TO FOLD FILTERS.



To form a filter, you are to proceed as follows. Take a piece of filtering paper $2\frac{3}{4}$ inches square; fold it in half, so as to bring the corners *c d* upon the corners *a b;* then fold it again, so as to bring the four corners together at *a;* cut off the corners, so as to form a quadrant, in the manner shown by the dotted lines in the under figure *a o;* and, finally, open the first fold, by separating the quadrant *b* from the other three quadrants, so as to produce, *o*, an inverted hollow cone. The letter *o* points out the position of the centre of the paper in all the figures.

PROPER SHAPE OF FUNNELS.

Procure a glass funnel, of the form of the annexed figure, and one and a half inch in diameter. This is large enough to

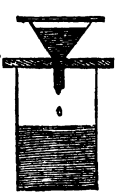
hold many precipitates which occur in qualitative analytical experiments. But larger funnels are also necessary, and are to be of the same form. They must always be made of glass. The paper filter, folded in the manner described above, is exactly formed to fit a funnel of this shape. The filter, when placed within the funnel, must not come within an eighth of an inch of the top, otherwise the liquid which may be poured into it is liable to run over, or, at the least, to evaporate and leave a portion of salt on the very edge of the paper, whence it cannot easily be washed back. There should be no loose places between the paper and the glass, no wrinkles in the paper, nor any fold or orifice to give passage sidewise to water that is put

upon any solid matter which the filter may contain. English funnels are generally made narrower and longer than this figure, and such funnels are objectionable. But it is possible to remedy in some degree the defect in their shape, by folding the double part of the filter after it is brought into the form *o*, one fold over the other, until the filter forms a narrower cone than one of which the sides make an angle of 60°, into which form the filter is thrown by simply folding the paper twice across. Funnels of a proper form, and of all necessary sizes, are now however kept for sale in Glasgow, at moderate prices. The best way to test the proper shape of a funnel is to cut a card into an equilateral triangle, and examine whether the sides of it fit the sides of the funnel into which it is inserted. When a funnel is of the proper form, its perpendicular section represents an equilateral triangle. Consequently, a card cut to this shape, with sides equal in length to the diameter of the mouth of the funnel, should turn round in the funnel and touch it on all sides alike. The neck of the funnel should descend from the apex of the cone, nearly of a cylindrical form. The most useful sizes of funnels for analytical experiments, are the six following, the four smallest of which are best adapted for qualitative analysis, and the others mostly employed in quantitative analysis. The funnel marked No. 1, is made with a very narrow neck, that it may serve the purpose of a filler for small vessels (page 15):—

Sizes of Funnels.	Diameter of the mouth.
No. 1.	1½ inches
2.	1¾ ——
3.	2 ——
4.	2½ ——
5.	3 ——
6.	4 ——

Equilateral triangles of card, having sides of these lengths, should exactly fit the respective funnels. No intermediate sizes of funnels are *necessary*, nor, for reasons that will appear in the sequel, *should be admitted* into a laboratory.

HOW TO SUPPORT FUNNELS.



The simplest method of supporting the funnel is to place the neck of it through a hole made in the middle of a piece of thin board, laid on the top of the glass cylinder which is intended to receive the filtered liquor.

The hole in such a board must be conical, or larger on one side of the board than on the other side, in order to suit the shape of the funnel. The board should be ¼ inch thick. The hole may be 1 inch wide below, and 1⅜ inch wide on the upper side. The triangular card serves to measure the proper angle of this hole, as well as of the sides of the funnel. Thin polished circular mahogany boards, with holes in the centre, imported from Germany,

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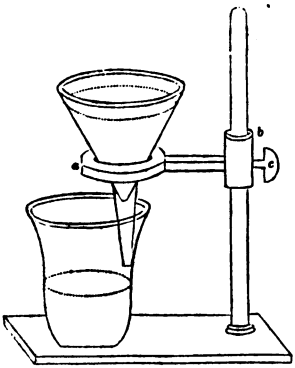
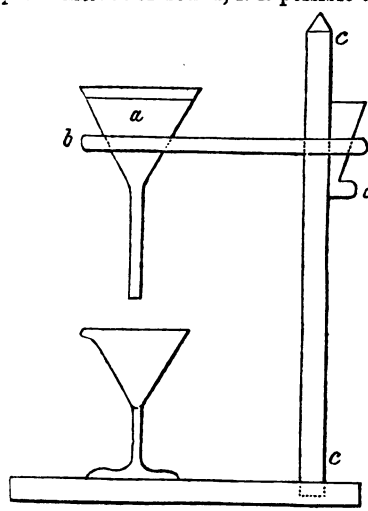
are now to be had in Glasgow, of various diameters, as are also circular plates of glass perforated in a similar manner, and ground smooth on the edges.

When the access of atmospheric air is to be avoided, as in the filtration of solutions that contain lime, alcohol, &c., the funnel must be covered with a plate of glass, and if the air is to be utterly excluded, the edge of the funnel and the surface of the glass plate must be ground so as to fit air tight.



Another method of supporting a funnel, is by means of a ring of wood fastened to an upright stand, and capable of being raised or lowered at pleasure, like the arm of the triangle retort stand formerly described. Such an apparatus is represented in the margin. The ring, or orifice, in the arm *a* is cut conically, so that the inner sides of the hole exactly fit the sides of the funnel, and consequently hold it firmly. The screw *b* serves to raise or depress the funnel according to occasion. This is the funnel holder employed by *Berzelius*.

When the upright rod of this filtering apparatus is made square instead of round, it is possible to fasten the arm which holds the funnel, by a small wooden wedge instead of a screw. This improvement is, I believe, due to Professor Graham. The instrument can then be made at a lower price, and thus constructed, it is, in fact, now sold in Glasgow, complete, for eightpence. The apparatus furnished for this small sum is adapted to hold any of the sizes of funnels above-mentioned. The figure in the margin shows the method of using it. *a* is the funnel which contains the filter; *b b*, the arm to



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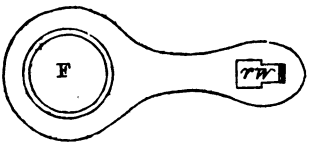
hold the funnel; *c c*, the square upright rod to support it; *d d*, the wedge to fasten the arm to the rod. Whenever the arm is required to be moved higher or lower than the point at which it may happen to be fixed, it can be instantly loosened from the rod by pushing the wedge *d d* a little upwards. The shape of the arm is best seen in the following figure, where F shows the place for the funnel, the two concentric circles around which represent the upper and under edges of the orifice, and where *r* shows the place for the rod *c c*, and *w*, the place for the wedge *d d*. I have recently improved this funnel holder by making the arm, F *r w*, of *glazed earthenware* instead of wood. The arm is about four inches in length, and the hole F is one inch wide on the under side. It holds safely any of the funnels enumerated at page 65. It is easily kept clean. It can be used with filters of a small size to *filter without a funnel*, since the conical sides of the orifice not only hold the paper securely, but are not liable, if kept clean, to communicate any impurity to it. Finally, the cost of the apparatus, consisting of China arm, with wooden rod and foot, is only one shilling.



I expect in a short time to receive from Berlin, some of the arm formed of *porcelain*.

THE ROUTINE OF FILTRATION.

If you pour a turbid liquid into a dry filter, the first portion of liquid which passes through has generally to be re-filtered, being often slightly turbid. But when the fibres of the paper are swelled by moisture, the liquor passes through in a transparent state. It is a good plan to provide against this necessity of twice filtering by moistening the filter with distilled water before you begin to pour in the solution. This enables you to fix the filter neatly in the funnel, and by preparing the paper, hinders the passing through of any turbid liquor. Moreover, it prevents the precipitate from being partially fixed in the pores of the paper, which sometimes happens when a turbid liquor is poured into a dry filter. This method should therefore be followed invariably. The small quantity of water necessary for the purpose of wetting the filter can be conveniently supplied by the washing bottle. The manipulation is as follows. You arrange the funnel holder, the funnel, and the glass that is to receive the filtered liquor. You fold the filter, open it, and catch hold of it near the top with the tip of the thumb and fore finger of the left hand, applied at the angle between *a* and *o*, in the small figure on page 64, in such a manner as to press the loose outside fold of the paper against the cone. You place the filter in the funnel, and retain it in its proper situation, by pressing it slightly with the tip of the forefinger. You then

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take the washing bottle in your right hand, blow air into it with your mouth, and direct the slight jet of water which issues from the tube, over the whole surface of the filter. The latter, when thus wetted, sits steadily in its place.

When the filtering apparatus is placed together in the manner shown by the wood-cuts, and the filter has been properly prepared, the liquor to be filtered is to be decanted into the paper, with the help of a rod, as described in the following article on "Decantation." The liquor should never be permitted to rise quite to the top of the paper filter, otherwise it will escape between the paper and the glass, and then run down into the clear liquor, contaminate it, and oblige you to perform the whole operation over again. The fuller you keep the filter, however, the quicker the filtration proceeds. Keep it therefore nearly full, but do not let it run over.

It is proper, in quantitative experiments, to let the point of the funnel *touch the inner side* of the vessel in which the filtered liquid is collected. The method is represented in the cut exhibiting Berzelius's apparatus. This prevents the splashing which occurs when the point of the funnel is fixed in the centre of the vessel, and at a distance above the collected fluid, as it is represented in the last cut. It is possible when this precaution is not observed, for part of the liquid to splash out of the vessel. The jar which receives the filtered liquid can be protected from dirt by a plate of window glass, having a bit cut out at one side to allow room for the neck of the funnel. In using a jar with straight sides to receive the filtered liquor, the point of the funnel is to be brought close to the side of the jar. Every drop which falls from the funnel is then attracted, during its fall, towards the side of the glass, which it touches before reaching the mass of liquid below, and consequently produces no splashing by its plunge.

If the solid substance to be separated by filtration, needs to be weighed, it is necessary to ascertain beforehand the weight of the filter. To this end, the paper after being cut to the proper size, is folded small, put into a counterpoised crucible or glass tube, and exposed to the heat of a sand or water bath till it ceases to lose weight. Its weight is then determined, and marked upon it with black chalk. But if the powder that is to be weighed needs to be ignited after filtration, then the paper may be burnt with it, and the ashes of the paper weighed with the powder. In this case it is only necessary to know how much ashes is left by a burnt paper filter of the same size and weight, in order to be able to deduct from the weight of the ignited powder, the amount of the ashes of the filter. This subject will be recurred to at the end of this article.

If you wish to filter broth, or any mixture containing animal matters, first run it through muslin, or a linen cloth, to clear it from the heaviest part of the solids it contains, and filter it through paper afterwards.

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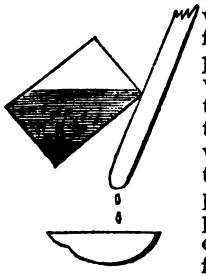
Strong acids and concentrated alcaline liquors cannot be filtered through paper. In general they can be best separated from impurities by decantation. (See "Caustic Potash.") They can however be filtered through a funnel filled with pounded glass or clean sand, a few larger lumps of glass being put into the neck of the funnel. Alcoholic solutions should be filtered under a bell glass, that the evaporation of the alcohol may be hindered. Should a bell glass not be attainable, the neck of the funnel must be stuck into the mouth of a flask, leaving only a small vacancy for air to escape; and the mouth of the funnel must be closed by a ground glass plate.

DECANTATION.

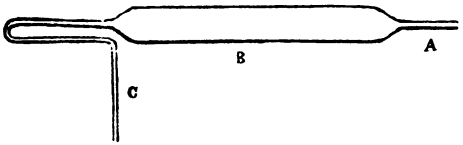


When you wish to remove a liquid from a solid which has subsided in it, or when you want to pour a liquid from a wide mouthed vessel into a narrow mouthed vessel, or from a solution flask into a filter, you may proceed as follows:—Apply a little tallow to the edge of the large vessel, dip a glass rod into the liquid, hold the middle of the wetted glass rod against the tallow and then by inclining the large vessel, make the liquid run gently down the rod into a vessel placed below the point of the rod to receive it. The tallow prevents the liquor from running down the outside of the large vessel. You must perform this operation without losing a single drop of the liquid. To prevent a loss by *splashing*, the lower point of the rod may be made to touch the inner side of the vessel into which the liquid is to be poured. The act of pouring from a cylinder is greatly facilitated when the edge of the glass is bent outwards, like that of the Beaker glasses depicted at pages 62 and 66. In decanting into a filter, it is a rule to let the stream run against the inner side of it, and not directly down the middle into the apex of the cone. When the first quantity of liquor put into a filter has run through, and more is to be poured in, it is particularly necessary to take care that the stream does not fall into the centre of the filter, as it would be almost certain to cause a splashing sufficient to throw drops of the liquor entirely out of the funnel. This is not so much to be feared when the accumulating precipitate has formed a round mass at the bottom of the filter.

When the vessel which contains a liquor to be filtered, happens to be very full, it is nearly impossible to pour from it into the filter without spilling a portion. It is proper to avoid this loss, by transvasing some of the liquor by means of a spoon of platinum or porcelain, which can be afterwards washed from it by the "washing bottle" described in the next section.

If the sediment from which you desire to decant a solution, be

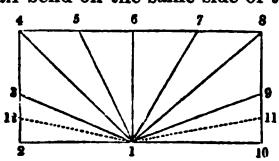
so light as to mix readily with the liquid when the vessel is gently moved, it is necessary to draw off the liquid without moving the vessel. The following figure exhibits an instrument



which is very useful in such a case. The part B may be three or four inches long and nearly an inch wide, the part A four inches long, and the descending part C, sufficiently long to reach the bottom of the vessel from which the liquid is to be withdrawn. In applying the instrument, you dip the point C into the liquid, and then, by applying the mouth to the upper end A, you suck the liquid into the reservoir B. When the liquid is small in quantity, the sucker, or dropping tube (page 58) may be used to remove it.

HOW TO FOLD RIBBED FILTERS.

When you wish to filter a liquid rapidly, to free it from impurities, it is sometimes proper to employ a folded or ribbed filter, like the annexed figure. To form this filter, you proceed as follows:—Take a square piece of paper, fold it into two, by doubling the corners *c d* upon the corners *a b*, as directed at page 64; then make the folds shown by the annexed diagram, and let them all bend on the same side of the paper. To produce 1 to 6, fold



10 upon 2; to produce 1 to 8, fold 10 upon 6; to produce 1 to 9, fold the line 1 to 10, upon the line 1 to 8; to produce 1 to 5, fold 2 upon 8; to produce 1 to 4, fold 2 upon 6; to produce 1 to 3, fold 2 upon 4; to produce 1 to 7, fold 10 upon 4. You have now 7 folds, all on one side of the paper, namely, folds 3 to 9. Next make a fold *between each of the above folds*, so as to rise on the other side of the paper. Begin by folding 1 to 10 upon 1 to 8, and turn back 1 to 10 upon 1 to 9. You will thus produce the reversed fold 1 to 11. Proceed in the same way to make a reversed fold between each of the other folds. When the paper is folded up, it looks like a child's fan. Cut off the projecting parts, so that the paper may look like a circle if opened out. Gently separate the two sides of the filter, and form it into a little cup. Put your finger into the cup, and push out the bottom till it is round. Upon examining the opened filter at the parts marked 10 and 2, you will find that

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there are two folds bending the same way. This defect you correct by making a small additional reversed fold in the parts which lie between 10 and 11, and 12 and 2. In rubbing down the folds, do not rub the paper near the centre 1, otherwise you will produce a hole. The funnel best adapted to contain a folded filter, is higher and narrower than the funnel figured at page 64. I cannot recommend this ribbed filter to be employed in any case where a precipitate is to be washed, for the multiplicity of its folds produce so many receptacles in which the solid matter can hide, that it is nearly impossible to cleanse a precipitate contained in such a filter entirely from the mother liquor. The ribbed filter was an improvement upon the method used formerly and still recommended by some persons, of promoting rapid filtration by making ridges in the funnel, or by putting glass rods or straws between the funnel and the filter; but contrivances of this sort are seldom of any use, and are often prejudicial. The best way to secure rapid filtration is to procure good filtering paper.

HOW TO FILTER WITHOUT A FUNNEL.

As it is often desirable in qualitative analysis to filter through very small filters, and as funnels of a proper size are in many places not easily procured, several methods have been contrived of filtering without funnels. One such method consists in placing the paper filter in the mouth of a test glass narrow enough to hold it steadily, such as the test glass described at page 54, or in the mouth of a small precipitating glass of Phillips's pattern. The latter answers best, in consequence of the greater space afforded for the reception of the filtered liquor. Paper filters of sufficient capacity to hold any weight of water not exceeding two ounces can be used with safety in this manner.—Another contrivance of the same sort is the China funnel holder already described. Paper cones from 1 to 2 inches in diameter can be held by it without a funnel. The filter described in a subsequent page, as "No. 2," is gripped by this funnel holder, near the upper edge of the paper, in such a manner as to prevent any of the liquor which passes through the filter from lodging on the upper surface of the china arm. But when a larger filter than No. 2 is used, some of the liquor that passes through the upper part of the filter runs upon the china arm, and thence into the vessel below. Hence it is necessary to keep the china arm scrupulously clean. In consequence, however, of this spreading of the filtered liquor over the support, this method of filtering without a funnel cannot be used in quantitative analysis.

A third method of filtering without a funnel is provided by the *filtering ring* of Professor Clark of Aberdeen, which is represented by *c* in the following figure.

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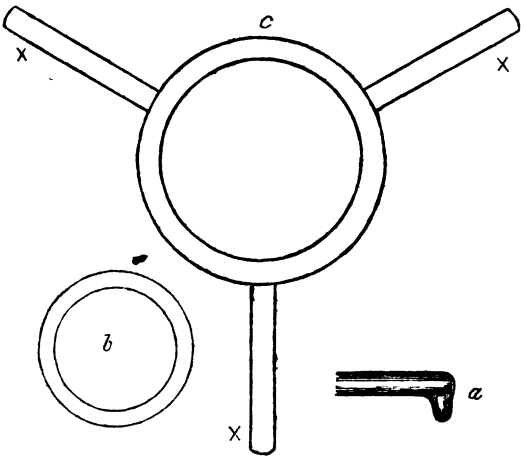


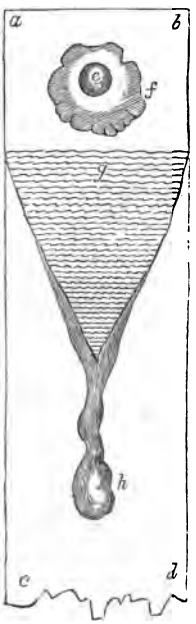
This is formed of glass rod, precisely of the size here depicted, and provided with three arms of the length denoted by x x x. The end of each arm is furnished with a little peg or knob as shown at *a*. A smaller size of this ring is represented by *b*. It should be made of thinner rod than the larger ring, but its arms should extend, like those of the larger ring, as far asunder as the points x x x.

In use, these rings are disposed in the manner shown by the annexed cut, where x x x represents a filtering ring placed on the top of a test glass, and *o* a paper filter fixed in the ring. The pegs or knobs *a* at the end of the arms x x x serve to keep the ring from slipping off the glass.—A filter, placed in a ring of this sort, can be filled to the brim without losing its shape or suffering the liquor to run down unfiltered, provided the paper is of good quality.

These filter rings could probably be made of white porcelain or cast glass. They should be flat, $\frac{1}{8}$ inch thick, the inner side of the ring conical, having the side inclined at an angle of 60°. They would then grip the paper cones firmly. The apertures should be $\frac{1}{2}$ inch, and 1 inch across below. These are the most useful sizes. The body of the ring might be $\frac{1}{8}$ of an inch thick, and the outer part a little rounded. It should have two flat arms, fixed to opposite sides of the ring. I give these proportions from wooden models of such rings, which I have tried.

Filters held in these rings allow the liquor to pass through them with rapidity so long as they are kept pretty full, but

they do not filter with rapidity to the end of the operation; on the contrary, a small quantity of the liquor remains long in the filter, and keeps the precipitate wet for some time after it would be dry, were a funnel used to hold the filter. The rings cannot be used, therefore, when a precipitate requires to be washed clean. They are chiefly useful when a liquor is to be quickly cleared from solid matter of no use, and where it answers the purpose in view, if the greater part of the liquor is readily got in a clear state, although a portion be lost. Thus, in exercising a class of students in qualitative analysis, wherein the filtration of small quantities of liquor occurs pretty frequently, as in the preparation of solutions, the separation of precipitates, and otherwise, these rings, supported upon conical test glasses, answer a good end.



A still simpler method of filtration can be occasionally employed in rough experiments. Suppose a solid substance to have been found by previous experiments to be soluble in nitric acid, but that it is desirable to know farther whether its solution in that acid is precipitable by one or two particular tests. You dissolve the substance, *e*, in nitric acid, *f*, on a slip of glass, *a b c d*, as directed at page 14. When the solution is effected, you place on the glass a triangular slip of filtering paper, *g*, with one side parallel to the solution and very near it. You then hold the end, *a b*, of the glass uppermost, and so cause the solution, *f*, to flow over the filter down to *h*, the other end of the slip of glass. It is thus rendered clear, and can now be directed by a glass rod to two or more separate points, to be tested with different reagents.

Cutting of Filters.—Wherever filtration has to be often performed, it is convenient to have papers ready cut in sizes to suit the funnels in most frequent use. This convenience is more especially felt when a number of persons are working together —for example, a class of practical (medical) students. If the filtering paper is kept in whole sheets, and not in sizes, there is, in the latter case, no end to the loss of time, and waste of paper, which is the infallible result of permitting or causing the students to cut filters one by one from whole sheets of paper.

I have recommended (page 65) that funnels be kept of certain regular sizes. It is equally expedient that there should be kept a supply of filtering paper cut into pieces adapted for these par-

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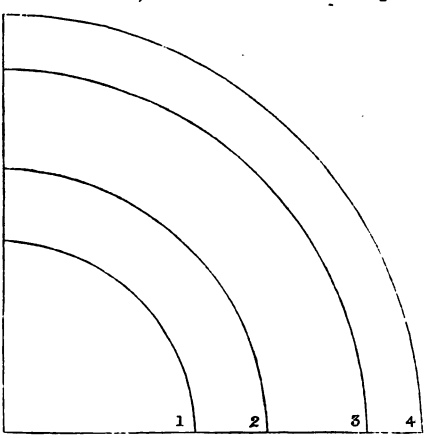
ticular funnels. I will add here a tabular view of the sizes of squares of paper adapted for such funnels as are found to be of most frequent use to persons engaged in chemical analysis.

No. of the funnels.	Diameter of the funnels.	Square of paper to measure at each side.
1	1¼ inch	2¼ inches
2	1½ ——	2¾ ——
3	2 ——	3¾ ——
4	2½ ——	4½ ——
5	3 ——	5½ ——
6	4 ——	7½ ——

These squares of paper on being folded twice, and having the corners removed by scissors or otherwise, (page 64) so as to leave a circular disc, produce cones that exactly fit funnels, the sides of which diverge at an angle of 60°, and that in all cases fill the funnels whose sizes are given in the table, excepting a space of ⅛ of an inch at the top.

I have, at page 64, described the method of folding filters, but I have yet to describe a contrivance by means of which the filters, when twice folded, can be cut into uniform quadrants with



facility. The above figure represents the sizes of four quadrants of tin plate, which can be used to guide the scissors in cutting off the corners of the paper when folded. They are adapted in size to the four smallest filters described in the above table. Every tin quadrant is kept in a little box with the square of paper to which it is adapted.

A still better method than this of cutting filters has been

recently suggested by Dr Mohr of Coblentz, whose paper (*Annalen der Pharmacie, Januar*, 1837,) has come into my hands at the moment when this sheet is going to press. His plan is to employ a quadrant of tin plate, having a rim $\frac{1}{8}$ or $\frac{1}{12}$ inch high along both its straight sides. With this he uses a second quadrant of such a size that when placed upon the first, and close to the straight rims, the outer circular edges of both become parallel to one another. The filters to be cut, first folded into squares, as I have already directed, are put, in thicknesses of five or six, between the two tin quadrants, and are cut close to the circular edge by shears.

Circular Filters.—Since the above article was written, I have succeeded, after many ineffectual attempts, in finding a method of cutting filtering paper into circular discs, adapted for filters to fit the prescribed (page 65,) sizes of funnels. The cutting machinery is simple, but powerful and expensive, and not adapted for private use. It consists of an arming press, worked by a lever of considerable power, and provided with a sharp circular steel knife for each size of filter. It is not therefore a machine for laboratory use, but the cutting is effected so easily and cheaply, that, where the machinery is at command, round filters can easily be prepared, and will now become an article of commerce, and be sold at moderate prices.

In using these filters, they have only to be twice folded across, as recommended for the square papers at page 64, when, upon being opened up, they present at once a cone of 60° adapted to the size and form of a filtering funnel.

Proper Paper for Filtering.—From what is said above, it is easy to see what are the properties of a good filtering paper. It should be *porous*, that the liquid may run through. It should be *smooth on its surface*, that the precipitate may not get into its pores, or become fixed over a large surface instead of being collected at the bottom of the cone. It should contain *no soluble matter*, else it will contaminate the solutions. It should be *thin in substance*, otherwise it will give too much charcoal when burnt, and may in some cases act as a reducing power upon ignited precipitates. It should give *no ashes* except the small portion which is the common product of calcined vegetable matter, and which should never be much more than $\frac{1}{2}$ per cent.

A filtering paper that filters slowly, says Berzelius, should never be used; for in filtering and washing precipitates with such a paper, you lose so much time, that you cannot make the same progress in your researches which you would do otherwise. It is best, he adds, to bespeak filtering paper for your own use at a paper mill. (A Scotch paper maker would hardly thank you for such an order.) It should be prepared from a pulp with long fibres, and in the winter time, in order that it may freeze while still wet, whereupon the water betwixt the fibres of the

paper becomes ice, and expanding, forces open the pores of the paper in all directions. A paper made in this manner filters much quicker than one of the same materials prepared in summer, and deprived of its water by immediate evaporation.

Two varieties of filtering paper are recommended by Berzelius. One variety of the thickness of common printing paper, the other as thin as fine letter paper, or as thin as it is possible to be made without holes. The first kind is intended to be used for large filters, and for experiments on unweighed quantities. The thin kind to be used in quantitative analysis.

Let us now see which of these characters are answered by the papers that are to be found in the stationers' warehouses, or that can be procured from the paper mills, of England and Scotland.

Post Letter Paper.—This can be got free from size, that is to say, in a bibulous state, but it filters very slowly in consequence of the close texture produced by the very finely ground rags of which it is composed, and by the hard pressing, and rapid drying, which attend the act of making it.

Printing Paper.—I have never been able to get any of this kind of paper unsized. In the manufacture of printing paper, as practised in this country, the size is mixed with the pulp before the paper is made, whereas the printing paper made abroad is without size, and our post papers are sized *after* they are made.

Plate Paper.—All the varieties that I have tried are stuffed with plaster of Paris. I think it probable that the pulp of which plate paper is made, if unmixed with sulphate of lime, and unbleached by chloride of lime, made into demy of 15lb weight to the ream, would make good filtering paper.

Red Blotting Paper.—The red coloured blotting paper cannot be used in consequence of the colouring matter it contains.

Laid White Blotting Paper.—The white kind of blotting paper constitutes the best filtering paper which is commonly to be procured. It has, however, several defects. It is always made with wire marks, and when wet is frequently either rotten or it exhibits numerous holes at these wire marks. It is bleached with chloride of lime, and frequently is not well washed from it. It sometimes contains plaster of Paris. It is often much too thick, and too firm in its texture to answer the purpose of filtration. However, a thin and tolerably pure article can sometimes be procured, which supplies good filters—but of the white blotting paper which is usually to be found in the shops, not above one ream in twenty is of this good kind.

Apothecaries' Filtering Paper.—Two sorts of paper of very thick substance, and rough surface, formed partly of woollen materials, are made for apothecaries' use. One sort is pale brown, the other and the roughest is blue. They filter with remarkable rapidity, and would be useful in clearing neutral solutions from dust or powder of no value; but as both sorts are

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unfit to gather precipitates upon, and as, in consequence of containing wool, they act chemically with solutions containing caustic alcalies or free nitric acid, it is not advisable to use them in analytical experiments.

Tea Paper.—A course cheap paper used by grocers, having a brownish white colour, and known to stationers' by the name of *small hand*, is sometimes sufficiently porous to be used as filtering paper. It is free from lime, and from bleaching liquor. It filters, however, but slowly; and the surface presents numerous small bits of straw and wood, which readily come off, and mix with the precipitate.

Swedish Filtering Paper.—Berzelius recommends a paper that is made at *Gryksbo* in *Dalarne*, Sweden, as being made expressly for filtering, and as answering the purpose completely. It is made, he says, with water so pure as to act upon no foreign substance, and which contains no earths. Acids and water extract nothing from this paper, and when burnt it yields no other ashes than such as are peculiar to pure linen, and of these not above $\frac{3}{5}$ per cent. of its weight. The makers of this paper, he adds, have such facilities for the manufacture of good filtering paper as are not easily to be equalled elsewhere, and that in consequence of these advantages they have recently prepared a quantity of this paper as an article of commerce. He neglects to add to this relation, the name of the manufacturer of this paper; in consequence of which neglect, it is as impossible for the English chemist to procure a supply, as it would be were the paper mill at which it is made situated in Utopia.

I have, however, procured some paper from Berlin, said to be Swedish, and I find it to be of very excellent quality. The sample which I received presented 0.575 grain of ashes in the 100.0 grains of paper. The size of it is that of English small folio post. The colour is yellowish white. The surface has a peculiar soft hairy feel. It filters with very great rapidity—a filter in a funnel $2\frac{1}{2}$ inches in diameter, sometimes gives a continuous stream of water, but other sheets are closer and filter slower.

The expensiveness of this paper in Germany, the cost of bringing it here, and the absurd duty of ninepence per pound weight levied upon it at our custom-house, added together, make the paper too dear for use in this country. It cannot be sold in Glasgow under 5s. 6d. the quire.

Filtrir Seiden-Papier.—A paper sold in Germany under this name, and described there as "fine filtering paper," is of the size of English royal printing paper, and in texture resembles our tissue paper, being as thin and as full of holes. It contains above 3 per cent. of ashes, among which is found the colouring matter of the paper, oxide of cobalt. It filters twenty times slower than the Swedish paper.

Filtrir Druck-Papier.—This is a variety of printing paper used in Germany for filtration. It is made with wire marks and has a strong bluish tinge, from the oxide of cobalt which it contains.

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It filters rapidly, but it contains 6.885 or nearly 7 per cent. of ashes. The German paper makers appear to colour their paper blue with smalt, instead of bleaching it with chloride of lime, as is done by our paper makers.

From my examination of the last two papers, which I procured from one of the first manufacturers of chemical apparatus in BERLIN, I am led to believe that the German chemists, with the exception of those who procure the Swedish paper, are worse provided with good filtering paper than we are in this country. The average quality of our thin wire marked white blotting paper of commerce is superior to both these German papers.

English Wove Blotting Paper.—Among the varieties of paper which have come to hand, while I have been engaged in the search for good filtering paper, is an article that bears a considerable resemblance to the Swedish filtering paper. It is of the size of demy printing paper, was sent to me under the name of *white blotting paper*, but, unlike all other sorts of white blotting paper that I have seen, it is not wire marked, but *wove* and of very uniform surface. The colour is whiter than that of the Swedish paper, it is of firmer texture, and far less easy to break when wet than the Swedish paper, which in that state is particularly rotten. It is thicker (heavier) than the Swedish paper in the proportion of 1904 to 1543. It filters slower than some sheets of the Swedish paper, but quicker than other sheets: generally speaking, however, it filters slower than the Swedish paper, though quicker than any other paper that I have tried. Possibly, if of the same weight as the Swedish paper, it would filter as rapidly. When ignited, it gives 0.42 in 100.00, or less than a half per cent, of ashes. This is less than the ashes of the Swedish paper, which in a comparative experiment gave 0.575 per cent.

This is, therefore, the best paper that I have yet examined, except the Swedish, and as it can be sold in Glasgow at less than a fourth-part of the price of the Swedish paper, namely at 1s. 9d. per quire of demy, while the Swedish is 5s. 6d. per quire of *post*, I have chosen this paper, as the material for the commercial circular filters. Consequently, the following circular filters are now made in Glasgow of this filtering paper, for sale, in packets of 100, at the following prices:—

No.	Diameter of the Funnel.	Price of the Funnel.	Diameter of the Filter.	Price of 100 Filters.
1	1¼ inch	6d	2¼ inches	3d
2	1½ ——	6d	2¾ ——	4d
3	2 ——	6d	3¾ ——	5d
4	2½ ——	6d	4½ ——	7d
5	3 ——	9d	5½ ——	8d
6	4 ——	1s	7½ ——	10d

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Ashes of Filters.—The ashes given by one of these filters is equal to the 238th part of its weight, or equal to *the weight of the filter multiplied by* 0.0042. In analysis, therefore, you dry and weigh the filter before use (p. 68) and when it is burnt with a precipitate you deduct from the weight of the ignited precipitate one-238th of the weight of the filter as the weight of the ashes of the filter. Thus, when a filter weighs 19.04 grains, you deduct from the joint weight of the precipitate and the ashes of the filter 0.08 grain, (19.04 multiplied by 0.0042) as the weight of the ashes of the filter.

WASHING OF PRECIPITATES.

EDULCORATION.

After having precipitated a substance, it is generally necessary to effect a complete separation of the precipitate from the solution. You must allow the precipitate to subside. It sometimes falls down very slowly; sometimes very quickly; in general, the subsiding is facilitated by gently warming the solution. The Beaker glasses (page 62), answer excellently for this purpose. In the case where alumina or peroxide of iron has been precipitated by an excess of ammonia, and where a salt of lime is present in the solution, the presence of atmospheric air must be cut off as completely as possible. This is effected by using a precipitating jar, of which the mouth has been ground smooth on a stone, so that it can be closed air tight by the application of a flat plate of ground plate glass, rubbed with a little tallow. The rim of the funnel in which the subsequent filtration is to be effected, should also be ground flat like the mouth of the jar. While a precipitate is subsiding, you prepare a filtering apparatus, like that depicted at page 66; and when the supernatant solution is clear, you decant it into the filter, taking the precaution of not disturbing the precipitate. When the clear liquor has nearly all passed through the filter, you stir up the residue with the precipitate, and bring the whole upon the filter, washing out the vessel with a little distilled water, and pouring the washings over the precipitate. When the precipitate adheres to the glass, so that it cannot be removed by the glass rod, you must rub it off with the point of a clean feather, or with the end of your forefinger, which must previously be washed very clean, and the precipitate on which must be carefully washed off by means of the *washing bottle*, or *edulcorator*, an instrument contrived by Berzelius, and of which I shall speak presently.

When the liquor has all run through the filter, and left the precipitate in a comparatively dry state, it is still necessary to free the latter from the portion of the solution with which, be-

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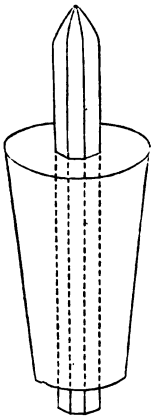
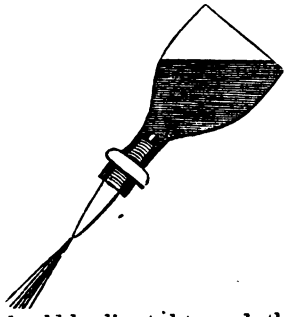
ing a very spongy mass, it must necessarily remain impregnated. You effect this by washing it with distilled water, by the help of the *edulcorator*, or washing bottle.

The edulcorator is a bottle the mouth of which is closed by a cork, through which a short piece of strong glass tube is passed; but so as not to project far beyond the cork. The size and shape of this cork and tube are figured in the margin. Another and an improved form of the tube is represented below. The price of such a tube is 2d. The



price of a washing bottle complete, varies according to its capacity. A 3 oz. bottle costs 1s —4 oz. 1s. 3d.—6 oz. 1s. 6d. These are the Glasgow prices of articles of German manufacture. The cork must fit the bottle very tight, and the external orifice of the glass tube must be very small, never exceeding the $\frac{1}{40}$ of an inch in diameter. It is handy to have two such flasks, one with a wider tube than the other, to give a larger stream of water when required. The orifice of such a tube can be widened by grinding it upon a sandstone, or rubbing it with a file which has been anointed with camphorised turpentine, or it can be narrowed by holding it in the flame of the spirit lamp, or before the blowpipe. The bottle should be rather more than half full of distilled water. If you hold the edulcorator with the cork downwards, and then put the point of the tube into your mouth, and blow air into the bottle, the water, upon your removing the point from your mouth, will, for a few moments, be expelled from the edulcorator with considerable force. It passes out in a fine stream, which can be directed upon the precipitate in the filter so as to stir it up and wash it with great ease and effect. Towards the end of the edulcoration, the jet of water should be directed towards the edges of the filter, and not upon the precipitate itself, by which means the precipitate is washed down to the bottom of the filter, and brought into a small compass. Precipitates of a gelatinous consistence require much washing. The jet of water is sometimes destitute of sufficient force to stir them up. In this case you may stir them with a



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small glass rod with a round end; but you must be exceedingly careful not to force the rod through the filter, otherwise the filtration will have to be repeated. It is to be observed that after every addition of water, no more is to be added till the first quantity is completely run through, otherwise you do not effect a washing of the precipitate, but only a continued dilution of the solution among it.

A prejudice appears to exist among British chemists, against the use of this most convenient little apparatus—arising, I believe, from a rash statement made by Mr Children, who affirmed that the water issuing from it must "squirt in the operator's face." A very clumsy operator must he be, who allows it to squirt in his face. I have no doubt, however, that the bottle "squirted" in Mr Children's face, or he would not have thought of putting the grievance into his book.

It often happens that precipitates require to be washed with hot water, in which case the edulcorator is particularly useful.

A flask, with a thin bottom, such as a Florence flask, or a gas bottle, is provided with a tube and cork, and is fastened to a wooden handle by the help of a steel wire. The figure distinctly shows how this can be managed. Hot water is poured into the flask, and is kept hot over a small oil lamp, used with the trellis and cylinder (page 24). In using this water, it is unnecessary to blow into the flask, since the steam produced by the hot water forces out the jet with sufficient rapidity, especially if the flask be gently shaken. Too violent a current is not desirable, as a tendency to splashing is apt to cause a loss of the substance under operation. A similar vessel can be used when a precipitate is to be washed with a saline solution.

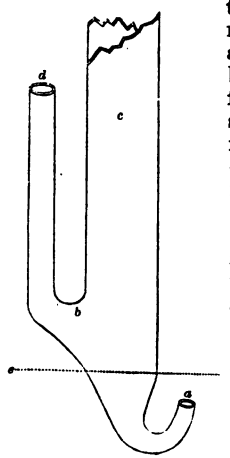
The edulcoration must be continued until the precipitate is completely freed from the solution in which it was produced. This is the case when the liquid which drops from the neck of the funnel consists of pure water alone. To find when this is the case, you take a drop of liquid from the neck of the funnel upon a bright piece of platinum foil, and evaporate the liquid to dryness over the spirit lamp. If it leaves no residue, it is pure water; if it leaves a stain, it still contains fixed matters, and the edulcoration must be continued. If a polished piece of platinum is not at hand, a similar trial can be made on a slip of clean window glass, upon which it is easy to perceive the stain produced by non-volatile matter. If the solution which runs through the filter contains sulphuric acid, muriatic acid, barytes, silver, or any other substance for which you possess a re-agent that acts as a very delicate precipitant, you may collect a drop or two of the liquid at the neck of the funnel, and test it with the appropriate re-agent. In this case you continue the edulcoration until the washings give no precipitate with the re-agent.

It is scarcely necessary to inform you that the neck of the funnel must never be allowed to dip into the filtered solution, for the liquor which runs from it can then never be collected for testing.

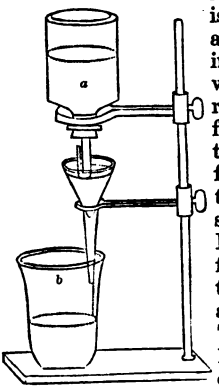
When the solution has passed the filter, and before the edulcoration of the precipitate commences, you change the cylinder which collects the filtering liquid, so that the wash water is collected apart from the original concentrated solution. In a qualitative analysis, the wash water is generally of very little value and may be thrown away—being frequently too dilute for testing, and generally containing too little solid matter to render it worth the trouble of concentration by evaporation, excepting always the cases where you are working upon scarce or valuable substances. But in a quantitative analysis, the wash water is of great importance, and must be carefully concentrated by evaporation, and then be added to the original solution.

Some precipitates can be washed by the following method, more readily than by filtration. It is a process, however, which is only adopted when no great accuracy is required, when the precipitate is alone valuable, and the solution of no consequence. The solution and precipitate are allowed to settle in a deep jar. The clear liquor is then decanted. The jar is filled with water, which is stirred up with the precipitate. It is again allowed to settle, again decanted, and so on repeatedly, till the solid matter is sufficiently washed.

The washing of precipitates takes up so much time, that it is advisable, in all possible cases, to adopt means either for shortening the operation, or for carrying it on without one's continued personal attention. The following method is often of utility in this respect. Its principle is that of making a column of pure water continually pass through the powder that is to be washed. The level of the water in the funnel is made to remain continually the same, by a contrivance which supplies fresh water from above as rapidly as the diluted solution passes out through the neck of the funnel below. A flask is filled with water, and is closed by a cork, having a glass tube of a peculiar shape shown in the margin *c*, passed through it. This tube must have exactly the form and size of the figure, with 1½ inch added to the tube *c*. When the flask is turned upside down, the water runs out only till the air within it is expanded to a certain degree, the capillarity of the tube *a* hindering the passage of any water thence into the air. But if the tube *a* is plunged into a liquid,

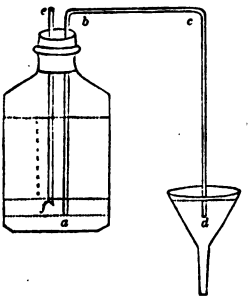


its capillary power ceases, and the water from the flask then flows through the tube *a*, into the liquid into which the tube was plunged. Very soon, however, the air in the flask becomes so much expanded, that the pressure of the atmosphere at *d*, forces down the water in that tube, and finally a bubble of air passes from the tube *d*, through the neck *b*, and ascends into the flask. This forces down a corresponding quantity of water, and every successive bubble of air that passes in by the same passage has the same effect. All this water, of course, flows out at the point *a*, and if that point is dipped into a liquid contained in a funnel, the level of the water in the latter is kept at the same point, as for example at the line *e*. It is the size of the opening *b*, as compared with the depth to which *a* is plunged in the liquid, which regulates the level of the water in the funnel. The annexed figure exhibits this apparatus complete. *a* is the water-flask containing the water, and having the pipe *a b c d* in its mouth. Below it, is seen the funnel, and at the bottom, the Beaker glass, *b*, for the reception of the filtered solution. The wooden part of this apparatus, of German manufacture, and large size, costs in Glasgow 7s. 6d. The tube fitted into the bottle *a*, costs 1s. 3d. It is however unnecessary that one frame should support all the vessels. The bottle *a* may be supported by Sefstroem's holder (page 39) which is required for other experiments, and the funnel by the usual funnel holder (page 66.)



If it be necessary to use hot water with this apparatus, the hot water is put into the flask, and the latter is covered with a wooden cap well stuffed with cotton wool, to hinder the escape of heat by radiation.

The annexed figure shows another method of washing precipitates by means of a self-supplying stream of pure water. The apparatus consists of a flask three-fourths full of distilled water, closed air tight by a cork through which two tubes pass. One of these *e f*, is straight, open at both ends, and having the lower end cut off aslant, to let air pass out more easily. The other tube, *a b c d*, also open at both ends, is a syphon with straight legs of the same length. The outer leg of this syphon is dipped into the liquid of the funnel that contains the substance intended to be washed. It is apparant from the construction



of this apparatus, that the tube *a b c d*, must act like a syphon with unequal legs, the working difference of the legs being equal to the space from *f* to *a*; so that if the water in the funnel should not escape so rapidly from the neck below, as it is replaced by the tube above, yet it cannot rise in the funnel higher than the level of the line *f*, since at that point the syphon becomes even-legged, and then carries over no water till the level again sinks in the funnel.

Solution of Precipitates.—It is frequently necessary to redissolve the solid compounds produced by precipitation, in order to subject them to the action of additional tests. The precipitates are gently dried on the filter till they acquire the consistency of soft dough, and are then removed from the paper, and put into the liquid in which it is intended to dissolve them. But when the precipitate is very small in bulk, or sticks very closely to the filter, or is much spread over the surface of the paper, it is often advisable not to attempt to separate it from the filter, but to expose it, paper and all, to the action of the solvent. It very seldom happens that the constituents of the paper can do any mischief. When the liquid has dissolved the precipitate, you filter the solution through a new filter, and thus separate the original filter from the solution produced by the precipitate. Another method of separating a precipitate from a filter is as follows:—You take the funnel which contains the filter and precipitate, still in a moist state, and fix it over the vessel which is to contain the solution produced by dissolving the precipitate. You then take the liquid which is to be employed as the solvent, and after making it boiling hot, if necessary, you pour it over the precipitate in the funnel. In passing through the filter it dissolves the precipitate, and separates it from the paper very neatly. In this manner peroxide of iron, which has been precipitated by ammonia, may be dissolved by hot muriatic acid.

EVAPORATION.

When a liquid is exposed to heat, it is converted into vapour or gas, which, if the vessel containing the liquid be open, flies away. The liquid thus heated is said to *evaporate*, and the operation of heating the liquid is called *evaporation*. If the liquid which is evaporated, holds in solution a substance of a fixed nature, this substance, after the evaporation of the liquid, remains behind in a solid state. The operation of evaporation is often employed by chemists on this very account. If you possess a mixture of salt and sand, and wish to obtain the salt in a separate state, you lixiviate the mass, filter the liquid containing the salt from

the insoluble sand, and afterwards expose it to evaporation. You thus obtain a product of clean dry salt, totally free from sand.

VESSELS FOR EVAPORATION.---The vessels in which evaporation is performed ought not only to be able to resist heat, but also the corrosive action of acids and alcalies, which often act in a very powerful manner, when present in concentrated solutions. They ought, moreover, to be of such a form as to expose a large surface of liquor to the atmosphere. Capsules of porcelain, or of silver or platinum (page 13) are most generally employed. The porcelain made at Berlin is much superior to that made by Wedgewood, both as respects its power of bearing sudden changes of temperature, and of withstanding the corrosive action of chemical fluids. Silver is properly adapted for the evaporation of alcaline liquors, and platinum for the evaporation of acid liquors. Watch glasses, broken pieces of Florence flasks, and crucibles of porcelain and platinum, can be used for the same operation, and even flat plates of glass are useful when single drops of a solution are to be evaporated. The vessels used for evaporation should always be thin at the bottom, in order that they may bear, without breaking, the sudden application of heat.

The porcelain evaporating basins made at Berlin, are of four different forms, and of many different sizes, as I shall mention.

All these varieties are now imported into this country, and are sold in Glasgow at the prices named below. The *first* of these varieties in form is figured in the margin. It is a round basin about three times as wide as it is deep, and furnished with a spout. The sizes and prices are as follows :---

Nos.	Diameters.	Prices.	Nos.	Diameters.	Prices.
00	2¾ inches.	6d	6	6 inches.	2s 4d
0	3¼ ——	8d	7	7½ ——	3s 0d
1	3½ ——	10d	8	8½ ——	4s 0d
2	3¾ ——	1s 0d	9	10 ——	6s 0d
3	4 ——	1s 3d	10	12 ——	9s 6d
4	4½ ——	1s 6d	11	13 ——	10s 6d
5	4¾ ——	1s 10d	12	15½ ——	31s 6d

The second variety of these basins consists of a semi-globular basin without spout. The sizes of this form are as follows ---

No. 000—1 inch diameter.	3d
1—5½ — ——	3s 0d
2—6½ — ——	3s 6d

The third variety is a basin about three times as wide as it is deep, without spout, but with the entire edge turned outwards in the manner of the solution jar figured on page 62, so that it is easy to pour a liquid from any part of the edge. The entire surface

of these basins is glazed, except a small central part of the outside.

No. 00—3½	inch diameter	6d
0—3¾	— ———	8d
1—3¾	— ———	10d
2—4	— ———	1s 0d
3—4½	— ———	1s 3d
4—4½	— ———	1s 6d
5—5	— ———	1s 10d
6—6½	— ———	2s 4d

The four sizes from 00 to 2 are all adapted to fit the perforated plate of the lamp furnace, page 25, §. III. They are sold in a nest for 3s.

The fourth variety of Berlin basins is nearly of the semi-globular form, but it is provided, not only with a spout, but also with a handle, all in one piece of porcelain. The form is exhibited in the margin. The sizes are as follows:—

No. 1—2	inches diameter	10d
2—2½	—— ———	1s 0d
3—3½	—— ———	1s 3d

A few additional vessels of Berlin porcelain, will be described in a subsequent section. The vessels are now on the way from Germany, but I have not yet seen samples of them.

There is a cheaper material than the Berlin porcelain used in Germany, in the construction of evaporating basins. It is called in that country *Sanitaetsgut*. Though inferior to Berlin porcelain, it is still superior to many varieties of earthenware evaporating basins made in England. A quantity of the Sanitaetsgut has been imported into Glasgow, where nests of six basins, from 2½ inches to 5 inches in diameter, are sold for 2s. 6d.

It is not easy to supply information respecting the prices of vessels of platinum, as they vary greatly. The following, however, are the prices of several small articles of that metal on sale in Glasgow in the summer of 1837.—1. Hemispherical cup, ½ inch diameter, with handle, 2s. This also serves the purpose of what is sometimes called a blowpipe spoon. 2. A cup of the same kind ¾ inch diameter, 5s. 3. Capsule of the size exhibited at page 14, with both spout and handle, 10s. 6d. 4. The same article, 1 inch diameter, 7s. 6d.

Process of Evaporation. From this account of the *vessels* for evaporation, I proceed to a description of the operation.—The solution which is to be evaporated must first be transvased into the evaporating basin from any other vessel in which it may happen to be contained, with due observance of the precautions which I have pointed out in the article on Decantation, page 69. The evaporating basin is then to be placed in the situation where it is to receive the heat necessary for vaporizing the fluid of the solution—for example, it is to be placed upon a sand bath over

the large furnace, (page 30) or the lamp furnace, (page 27) or in [illegible] perforated plate of the lamp furnace, (page 27) or upon the [illegible] support over a lamp (page 37).

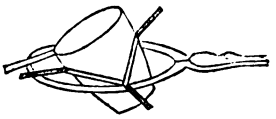
[illegible] vessel in which a solution is evaporated, should, during the operation, be covered; partly to prevent the contamination of the product by dust, and partly to prevent a loss of matter by ebullition or spirting. When the evaporation is slow, and no spirting is produced, two glass rods may be laid across the capsule, and a double fold of blotting paper be laid upon them. This paper should be changed as often as it becomes so soft, or much corroded by acid steams, as to be liable to fall into the solution. A different method of protecting the capsule, consists in putting a larger capsule upon it, and filling the upper capsule with hot sand, to keep it from condensing the steam which rises from the solution. Small capsules, or a crucible, may be covered by the platinum capsule (page 14), placed upon them in such a manner as to allow a space for the escape of the vapour. In all cases, the cover must dip downwards, in order that the fluid, which is thrown upwards, or condensed upon it, may return to that below. If the convex side of the cover were uppermost, particles of matter existing in drops of the solution could be conveyed to the outside of the vessel and be lost.

The contents of a capsule should be frequently stirred during evaporation, by means of a glass rod. Lumps of saline matter, and hard dry crusts, should be broken down with great care.

When a solution is to be evaporated to dryness, much caution is necessary in conducting the operation at the period when the mixture becomes thick. A very gentle heat must then be applied, and the mixture of solution and solid matter must be stirred continually. If this care is not taken, part of the contents of the vessel are invariably thrown out by the sputtering of the pasty mass. All hard lumps which appear must be broken down, and the powder be well mixed with the moist substance. If the lumps are too hard to be broken by a glass rod, a small pestle may be employed for that purpose; care being taken, in an analysis, to wash from the pestle the matter which may adhere to it, and to preserve the solution to add to that formed by the subsequent solution of the evaporated mass.

When large quantities of liquid are to be evaporated at a boiling temperature, as, for example, when a mineral water is to be concentrated for analysis, the evaporation may be effected in a Florence flask, or still better, in the thin solution jars pictured on page 62. These can be very properly heated over the lamp furnace.

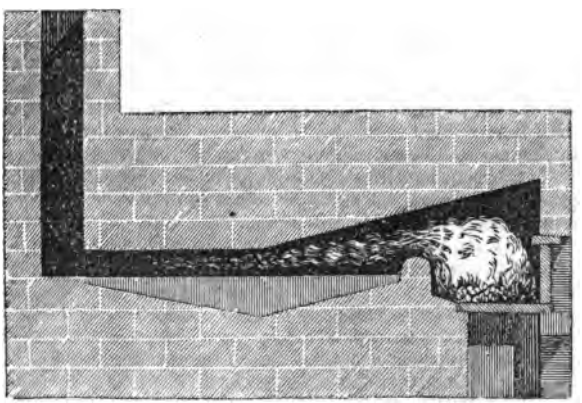
It sometimes happens in analytical experiments, that a heavy powder lies at the bottom of a solution which is to undergo evaporation. When heat is applied to the evaporating vessel in such a case, it often accumulates at the bottom, so as to produce a series of explosions, which scatter the solution out of the vessel. This accident is best avoided by putting the solution into a cru-



cible, or any other deep vessel, fixing it aslant on a triangle, port, and placing the lamp in a position beneath, as to make the flame strike against the side of the upper edge of the solution, rather than against its bottom. The evaporation then proceeds quietly and rapidly.

Evaporation in Close Vessels.—The vessel containing the solution which is to be evaporated, is placed under the receiver of an air pump, in company with another vessel containing a substance which eagerly attracts moisture, such as strong oil of vitriol, fused chloride of calcium, or calcined potash. The air is sometimes exhausted, and sometimes not. The evaporation proceeds with greatest rapidity when the receiver is exhausted.

Evaporation in the Large Way.—In general, when a liquor is to be boiled, the heat is applied below the vessel containing it; but in chemical manufactories, where it is necessary to evaporate very large quantities of liquor at a small expense, it is common to employ stone boilers contrived in such a manner that the heat may be applied to the surface of the liquor. These boilers are large oblong chambers, with a brick arch built over them, a fire place at one end, and a chimney at the other, proper openings being also provided for inserting or examining the subject of operation. The fire being lighted, the flame plays along the surface of the liquor, which by this means is evaporated. Boilers or furnaces of this kind are sometimes made of sufficient capacity to contain ten thousand gallons.



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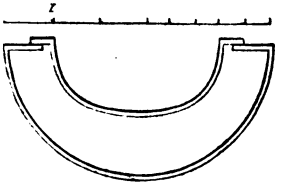
WATER BATH.—A vessel heated in boiling water, or in the steam arising from boiling water, never becomes heated above the boiling point of water. Hence, a *water bath*, a vessel so contrived as to hold water, always boiling, and to afford means of applying its heat to other bodies, is found to be of great use in chemical laboratories, in cases where a moderate and regular degree of heat is required to be long sustained. In the drying of precipitates; in evaporating for crystallisation, such solutions as su[illegible] decomposition when heated above a certain moderate [illegible]ature, such as the red prussiate of potash; in the prepar[illegible]f vegetable extracts; and in experiments with organic [illegible]ces of various kinds, the water bath becomes very service-

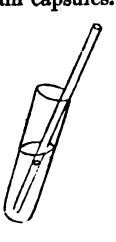
A familiar example of the use of the water bath is presented in the common carpenters' glue pot. The most convenient water bath for a large laboratory consists in a copper boiler, built into a furnace, and covered with a flat top perforated with holes of different size. Flat plates of copper are provided to close these holes when necessary, and crucibles, flasks, and capsules, are inserted into them to be heated. A doubled bit of paper is put between the flask and the edge of the hole on one side, to prevent the crushing of the vessel in the event of contraction of the metal by cooling, taking place accidentally.



For use in the small way, the most convenient *water bath* yet contrived, is an apparatus composed of two pieces of Berlin porcelain, the form of which is exhibited in the section drawn in the margin. Three sizes of this apparatus are now to be had in Glasgow:—

No. 00—4½ inches diameter 3s
0—5 —— —— 4s
1—5½ —— —— 6s 6d

The water to constitute the bath is boiled in the under vessel, which is supported for that purpose over a gas light or spirit lamp, by means of the lamp cylinder, page 24. The substance to be evaporated or dried is put into the upper vessel. The whole apparatus is glazed, and of the same nature as the Berlin porcelain capsules.



The annexed figure represents a miniature water bath. The wide glass tube contains water supposed to be boiling over a lamp. The long narrow tube contains the substance under experiment, which in this position is subjected to the heat of boiling water as long as the heat and the supply of water is kept up.

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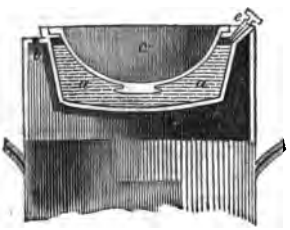
Drying of Precipitates.—After filtration and edulcoration, it is often necessary to dry the precipitate which remains on the filter. The latter is carefully drawn out of the funnel, and placed upon several folds of blotting paper, and the whole is then laid in the upper capsule of the water bath. In common experiments, the filter and its contents can be rapidly dried by being placed upon a warm brick, which readily absorbs the moisture. In careful experiments, the use of the water bath cannot be replaced by that of the sand bath, because the sand often becomes too hot without it being perceived, and is liable to do mischief.

Drying of Glass Vessels.—While speaking of different methods of driving away water by evaporation, I may notice the way in which moisture can be expelled from flasks, retorts, long glass tubes, and the like. To do this, you warm the vessel that is to be dried. You insert a long glass tube till the end nearly reaches the bottom of the vessel. You then blow air with your mouth into the other end of the inserted tube. The heat vaporizes the water, and the current of air thus produced, immediately carries off the vapour. It is still better to suck the air through the tube than to blow it through.

Salt Bath.—A saturated solution of common salt boils at 228° Fahrenheit. This temperature can, therefore, be conveniently applied, on the same principle as the heat of boiling water is applied, to the heating or evaporating of liquids which cannot be placed over the naked fire without danger of burning, exploding, or boiling over, or of occasioning the destruction of the vessel in which the operation takes place. The apparatus for this salt bath greatly resembles the porcelain water bath, described above. It consists of a copper kettle for containing the solution of salt, which is supported over a charcoal fire, and provided with an upper vessel to hold the solution that is to be evaporated. When the solution of salt *a* is at a particular state of concentration, it gives all the heat it receives from the fire to the vessel placed within it *c*, where the evaporation then proceeds. The kettle *a* is provided with a stop cock *e*, which permits the solution of salt to be brought into occasional connection with the atmosphere.



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CRYSTALLISATION.

When fluid substances are suffered to pass with adequate slowness to the solid state, the attractive forces frequently arrange the ultimate particles of the substances in such a manner as to form regular geometrical solids, to which has been given the name of *crystals*.

Perfect mobility among the corpuscles is essential to crystallisation. The chemist produces it either by igneous fusion, by vaporisation, or by solution in a liquid. When the temperature is slowly lowered in the two former cases, or the liquid slowly extracted by evaporation in the last, the attractive forces resume the ascendency, and arrange the particles in symmetrical forms. The formation of crystals by solution is effected in vessels such as have been described in the articles on "Solution" and "Evaporation," particularly in the porcelain evaporating basins, described at page 85. Bodies that crystallise from watery solutions, frequently retain a small portion of water, which remains confined in the crystals in a state of solidity, and does not reappear till the crystalline nature of those bodies is destroyed. This water is called *water of crystallisation*. The mode of obtaining crystals of certain bodies, differs according to their particular habitudes. If it be desired to obtain crystals of a salt that is more soluble in hot water than in cold, all that there is to do, is to put into hot water as much of that salt as it will dissolve, to make, in short, a hot saturated solution, and then to allow it to cool gradually, the slower the better. As the heat which contributed to the fluidity of the salt flies off, crystals will be deposited at the bottom of the vessel. Salts that are soluble in equal parts of hot and cold water, can only be crystallised by driving off the water of solution in vapour. But this must be done very slowly; for rapid evaporation leaves a salt, not in a crystallised state, but in that of a solid irregular mass. By the operation of crystallisation, salts which differ in their degree of solubility, or whose solution is unequally accelerated by heat, may be obtained separately from the same liquid. Thus, if two salts be dissolved in the same liquid, and one of them be much more soluble in hot than in cold water, and the other be equally soluble at any temperature, then, on evaporating the solution sufficiently, the latter salt will crystallise while the liquor is hot, whereas the other will not shoot into crystals until the liquor is cold; thus, by alternate evaporation and cooling, the two salts may be obtained uncombined, though perhaps with a little intermixture of each other.

The only general rule that can be given, for the purpose of directing you how to crystallise bodies, is this: Slowly evaporate the solution, until a pellicle, or thin skin, is formed on the surface of it; then set it in a cool place, where it will be free from

dust, and can remain undisturbed. This rule will not, by any means, apply to all salts, nor is there any other rule that will. Nothing but experience, and a knowledge of the habitudes of the various crystallisable substances, can be of much avail.

Many saline solutions, when set by to crystallise, throw out ramifications of dry salt, which creep over the edge of the basin, and, if not interrupted, extend over the entire outer surface of the basin, and along the contiguous table. This is prevented by rubbing a little tallow round the edge of the basin, or by using a porcelain capsule with a burnished gold edge. When a solution is to be cooled slowly, the vessel should be placed on cushion, and covered with a few folds of cloth. When a solution is to be exposed to spontaneous evaporation, a process which produces large and regular crystals, the vessel should be placed in a dry situation, and be left uncovered, or only be covered with a piece of paper to keep out the dust. When crystallisations are performed on the small scale, flat plates of glass, watch glasses, and the platinum capsule (page 13), are useful; but in general, deeper vessels are preferable. A solution set by to crystallise, should be contained in a vessel so shaped that the liquid may be about twice as wide as it is deep. Consequently, very shallow or very narrow vessels are not so well adapted for this operation as those are which have the form of basins. Rough surfaces and porous substances promote crystallisation.

Crystallisation is a process very frequently resorted to by the chemist, in some cases for the purpose of producing bodies of regular form, from which to infer the nature of an unknown substance submitted to experiment, but more frequently as a means of separating a crystallisable compound from various impurities not susceptible of crystallisation. In nearly all cases where a chemical substance is required in a state of purity, to be used, for example, as a re-agent, or to be employed in quantitative analysis, or in the preparation of substances for such uses, it is almost the general plan of the chemist to begin the preparation of that pure substance with a salt, previously purified by several successive crystallisations, from solutions effected in distilled water. Thus, pure potash and soda are prepared from pure crystals of the carbonate or nitrate of those alcalies, pure barytes from crystals of the nitrate of barytes, pure muriatic acid from purified crystals of chloride of sodium, pure nitric acid from purified crystals of nitrate of potash, and so on.

Solutions prepared in other liquids than water, often yield crystals that contain other compounds than those submitted to solution—crystals in which a certain quantity of the solvent assumes the solid state, precisely in the same manner as water does in such crystals as are said to contain water of crystallisation. Thus, sulphate of potash, dissolved in oil of vitriol, produces crystals which in a dry state consist of sulphate of potash, and oil of vitriol. Many salts, dissolved in alcohol, produce, as Professor

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GRAHAM has shown, dry crystals, which contain a certain proportion of alcohol.

When a solution is slowly evaporated, the crystals obtained are large and frequently grouped together, so as to form hollows of a considerable size. These hollows retain a portion of the mother liquor, which consequently contaminates the crystals. To prevent this retention of mother liquor by a crystallising salt, it is only necessary to stir the solution while it crystallises, and thus prevent the formation of large crystals. This method is practised in the manufacture of refined sugar, saltpetre, and various other substances.

When crystallisation is to be effected on the small scale, for the purpose of determining the form assumed by a salt on crystallisation, flat plates of window glass answer the purpose tolerably well. A slip such as that described at page 14, is held flat by one end; a drop of the solution, an inch broad, is placed near the other end, and is warmed over a lamp. When the edges of the drop begin to look white and dry, you remove the flame and let the drop cool; whereupon crystals soon appear, affording by their forms, though generally incomplete, indications of the nature of the salt submitted to examination. For example, drops of solutions of nitre and common salt, of alum and sulphate of soda, tried in this way, afford results not easily confounded with one another, by one accustomed to observe crystals.

The formation of crystals by fusion occurs with such substances as sulphur, lead, and bismuth. It seldom succeeds except when tried with large quantities of the substances. See "Sulphur."

The operation of crystallising by vaporisation, will be explained in the article on "Sublimation."

EXERCISES AND CLASS EXPERIMENTS.

1. Dissolve a quantity of saltpetre in water with the aid of heat. Set the solution aside in a deep basin to crystallise. Pick out the best crystals, and preserve them as specimens. Evaporate the liquor again, to furnish a second crop of crystals.

2. In the same manner, prepare and crystallise solutions of sulphate of iron, sulphate of copper, sulphate of soda, sulphate of magnesia, and alum.

3. Dissolve equal weights of saltpetre and carbonate of potash in a small quantity of hot water, and allow the solution to cool in a capsule. The greater part of the saltpetre will separate in crystals, but the whole of the carbonate of potash will remain in solution in the residual liquid, or mother water.

4. TO MAKE CINDERS, OR LITTLE WICKER-FIGURES, APPEAR AS IF THEY WERE CRYSTALLISED.—Saturate water *kept boiling*, with alum; then set the solution in a cool place, suspending in it, by a hair, or fine silk thread, a cinder, a sprig of a plant, or any other trifle; as the solution cools, a beautiful crystallisation of the salt takes place upon the cinder, &c. which are made to resemble specimens of mineralogical spars.

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5. *To make Coloured Crystals of Alum.*—Method of proceeding.—Hot saturated solutions of alum are mixed with various colouring substances, and are then submitted to crystallisation. Colours to be used:—The addition of powdered turmeric produces transparent *yellow* crystals. Powdered litmus produces transparent *red* crystals. Logwood makes them *purple*, and common writing ink *black*. The more troubled the solution looks, the finer are the crystals it affords, so that filtration is not necessary. These coloured crystals are more easily destroyed than those of pure alum. The best way to preserve them is to support them under a bell glass, which rests in a capsule that contains a little water. This arrangement produces a moist atmosphere, which is not only useful in this case, but also for the preservation of crystals of sulphate of copper, and various other salts whose colours are dependant upon their water of crystallisation.

The crystallisation of alum is promoted by hanging in its solution substances with rough surfaces, such as coke, cotton, porous wood, and pumice stone.

6. To obtain Large and Beautiful Artificial Crystals.—This operation requires considerable address, and much patient attention; it is as follows: a solution of the salt to be crystallised is to be slowly evaporated to such a consistence that it shall crystallise upon cooling, which may be known by letting a drop of it fall on a plate of glass. When it is in this state, set it by; and when it is cold, pour into a flat bottomed vessel the liquid part of the solution off the mass of crystals which will be formed at the bottom of it. After a few days solitary crystals will be formed, which will gradually increase in size. Pick out the most regular of these, and put them into another flat-bottomed vessel; and pour over them a fresh solution of the salt evaporated till it crystallises on cooling. After this, alter the position of every crystal once a day with a glass rod, so that all the faces of it may be alternately exposed to the liquid; for the face on which the crystal rests never receives any increment. By this process the crystals gradually increase in size. When they are so large that their forms can be easily distinguished, take the best of them, and put each into a vessel separately; add a fresh solution of the salt as before directed, and turn every crystal several times a-day. By this treatment you may obtain them almost of any size you wish. It is necessary to pour off the liquid from the crystals, and add fresh liquid in its place, very frequently; for the solution, after depositing a certain portion of its salt, becomes weakened, and then attacks the crystals—rounding off their angles in the first place, as an attentive observer may perceive, and infallibly destroying them, unless renewed.—The student may endeavour to form thus a regular crystal of *alum*, to exercise his dexterity.

7. Instantaneous Crystallisation: A curious example of the production of heat, by the conversion of a liquid into a solid.—Into two ounces of boiling water, put as much sulphate of soda, as it will dissolve (about three ounces). Pour as much of this saturated solution, when boiling hot, into a phial, as will nearly, but not quite, fill it; cork the phial closely, and let it stand to cool. When cold, the solution is still fluid; but the instant you draw the cork, a very beautiful, but confused crystallisation, of the whole mass, immediately takes place; and, at the same time, so much heat is evolved as to make the phial warm.

The explanation of the experiment is this:—Water dissolves more sulphate of soda when hot than when cold; and cold water dissolves more in proportion as the pressure of the atmosphere is diminished. The hot water is here saturated, and, if it had been suffered to cool in an open vessel, would have deposited part of the salt. But, in

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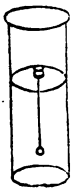
this case, none is deposited, for by suffering the solution to cool in a close vessel, a partial vacuum is produced at the surface of it, (the steam which occupied the top part of the phial when the cork is inserted, being, by the subsequent cold, condensed,) and the water, when cold, is thus enabled to hold in solution, all the salt which it had dissolved when hot. As soon, however, as, by drawing the cork, you admit the usual pressure of the atmosphere, the cold water is rendered incapable of holding so much salt in solution, and part is, therefore, instantly crystallised. The heat which is evolved, is the heat of liquidity of the portion of the salt which thus becomes solid. If, when the salt has crystallised, you plunge the phial containing it into hot water, it will be again dissolved. You may then cork the phial, as before, and the same solution will serve for a repetition of the experiment.

8. Dissolve 4 parts of crystallised sulphate of soda, and 3 parts of saltpetre, in 15 parts of warm water. Divide the solution into two portions. In one of these portions place a crystal of saltpetre, and in the other a crystal of sulphate of soda. Cover up the two solutions that they may cool slowly without evaporation. The first solution will deposit only saltpetre, and the second only sulphate of soda. This phenomena is explained by assuming that the attraction between the particles of saltpetre and saltpetre, is greater than that between saltpetre and water, or between saltpetre and sulphate of soda.



9. The following is a neat way of promoting the crystallising of salts in small solutions. Put a cold saturated solution of any crystallisable salt into a deep jar, and hang in it a line of silk or horse-hair, fastening a shot to the bottom of the line, and a bit of cork to the top. Set the solution aside, and you will soon perceive crystals to form about the shot, and along the line. Sugar will crystallise on threads fixed across a pan.

IGNITION.

It is often necessary to make a substance red hot, either to free it from water, to burn it, melt it, or to decompose and char any organic substances which it may contain. Sometimes the ignition may be performed in a Hessian crucible, or in a porcelain crucible, or for want of that, in a clean tobacco pipe. But in most cases, the vessel in which a substance is exposed to ignition, is best when made of platinum; only, it is necessary to remember, that platinum vessels can never be employed when reguline metals, such as uncombined lead or copper are likely to be produced by the ignition, or where free chlorine is likely to be disengaged during the experiment; as, for example, when muriatic acid comes into contact with the peroxides of manganese or of lead. See "Platinum."

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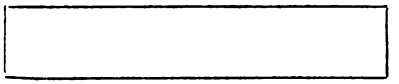
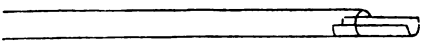
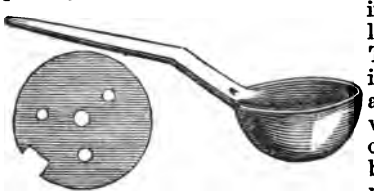
Platinum Vessels.—The simplest form of an instrument for ignition is a piece of platinum foil, as thick as stout writing paper, and as large as the figure in the margin. The substance to be ignited is placed on one end of the foil, which is previously hollowed a little by the pressure of a finger, and is then exposed to the flame of a spirit lamp or the action of the blowpipe.



This foil can be made intensely hot before the blowpipe, because the thin metal carries away very little of the heat applied to it. When a substance is to be at once heated and oxidised, both objects can be effected by directing the blowpipe flame upon the bottom of the foil immediately under the substance to be heated. Platinum is so little qualified to conduct heat, that a piece of foil of the above size can be held at one end by the fingers, while the other is raised to a white heat. I refer you to the section "on the use of the Blowpipe," for an account of the method of managing that instrument. The price of this useful piece of apparatus (the platinum foil) is 8d. When it becomes ragged at the end from much use, or is perforated by the accidental fusion of a metal upon it, the part must be cut off. When it is worn too short to be conveniently held by the fingers, it can still be supported by one of Mordan's holders for steel pens, or by insertion in the end of a small glass tube, thus—

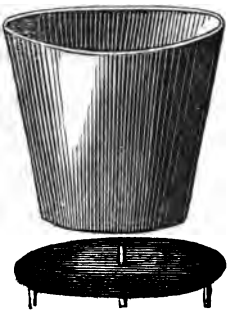


When a substance is to be heated with fluxes, or when the quantity is somewhat considerable, it is convenient to ignite it in a little platinum spoon like the annexed figure. This spoon should be stuck into a tobacco pipe handle, and should be provided with a cover. The latter ought to have three pegs below to keep it in its proper place on the spoon, and a centre peg on the upper side to serve for a handle. For certain experiments, a silver spoon of this form is convenient; but though such a spoon is much cheaper than one formed of platinum, it is too fusible and too easily acted upon by acids, to be generally useful. The chief use, indeed, of a silver spoon, is to assist in decomposing certain minerals, and the salts of the metallic acids, by fusion with caustic alcalies. The cost of a platinum spoon of this description is eight or ten shillings.



Platinum cups of the form and size represented at page 14, or hemispherical cups, half an inch or three-fourths of an inch in diameter, are also very useful vessels for ignition. When they

are to be exposed to heat they may be held by the blowpipe tongs, or be supported over a lamp on a triangle of very fine iron wire. The smaller sort can be placed in a cavity made on a piece of charcoal, and heated before the blowpipe, as will be described in another section. These cups should have on one side a projecting slip, a quarter of an inch long, to serve as a handle. The price of them is 2s. for one of $\frac{1}{2}$ inch in diameter, and 5s. for one of $\frac{3}{4}$ inch in diameter, with handle.

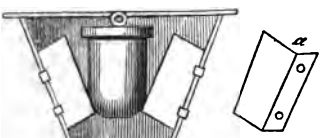


An instrument more generally useful than the platinum spoon, but at the same time more expensive, is the platinum crucible, which with its platinum cover, is represented in the margin. The cost of a vessel of this size is about £2. But those who wish to make experiments in qualitative analysis only, can have one made smaller and slighter for about £1, or still smaller, and without cover, at from three to ten shillings.

The crucible cover represented in the margin, is nearly flat, and provided with three pegs to keep it in its place. This is the usual French form. In London, the covers are commonly made to fit close to the body of the crucible by means of a rim, like the cover of the porcelain crucible, of which a drawing is given at the foot of the next page.

Platinum crucibles must not be made too thick, because the metal is very heavy, and the crucible, when loaded, becomes inconvenient to weigh in a delicate balance.

The figure on page 19, shows in what manner a platinum crucible can be supported over a spirit lamp. The annexed figure shows a contrivance, by means of which the heat produced by a spirit lamp can be concentrated and increased. It is a cone of tin plate $2\frac{1}{2}$ inches deep, $1\frac{1}{2}$ inch broad at bottom, and $3\frac{1}{2}$ inch broad at top. Within it, and fixed equidistant from each other, are three plates of iron *a*, $\frac{1}{2}$ inch wide, and 1 inch long, fastened by flanges to the cone, so as to present a support for a crucible in the shape of three edges, which separate as they proceed upwards. A crucible placed in this cone, as shown in the figure, receives the benefit of the flame much more effectually than when it is supported simply by a ring or a triangle. Of course, the bottom of the cone is made to correspond with the top of the chimney of the lamp.



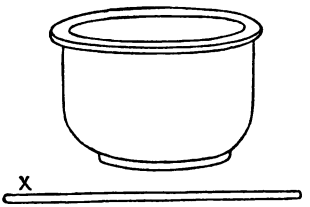
An improved Berzelius's lamp, which I received very recent-

ly from Berlin, was accompanied by a small iron dome for concentrating the heat about a crucible, when supported over the lamp by a triangle, as shown at page 19. The dome was of the shape of a sugar loaf, with the upper point cut off, and the broad end a little expanded. The height of it was 4 inches. The width $2\frac{1}{2}$ inches, diminishing to $1\frac{1}{2}$ inches. It was supported on the lamp rod by a brass arm, and could be brought down closely to the triangle, so as entirely to cover the crucible, and protect it from any air but that which came hot from the flame.

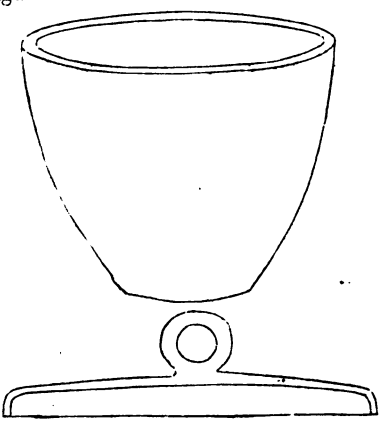
When placed in a furnace, the platinum crucible requires to be enclosed in a round Hessian crucible, provided with a foot and cover, to prevent its contact with the fuel.

In many cases, where metallic crucibles are objectionable, for the reasons that will be stated under the article "Platinum," it is proper to employ crucibles of porcelain, although it is impossible to heat a substance so powerfully in a porcelain as in a platinum crucible, particularly over a lamp.

Porcelain Crucibles.—For the fusion of chloride of silver, for the ignition of a variety of precipitates, and for numerous other purposes, the small porcelain cups, described at page 13, are useful vessels. They are to be had of two sizes. When in use, they may be supported by the same means as the platinum crucibles. Covers for them are afforded by the smallest size of porcelain capsule.



But, independently of these cups, we get from Berlin, porcelain crucibles, with covers, of the form shown in the following figure. Two sizes are made. The smallest $1\frac{3}{4}$ inch, the largest $2\frac{1}{4}$ inch in diameter. These crucibles are of very excellent quality, glazed within and without, and so well able to suffer transitions of temperature, that the cover may be put cold upon the crucible when red hot, without producing fracture. The glazing withstands the action of strong acids. The covers are not nearly so liable to split as are those of English manufacture, and in



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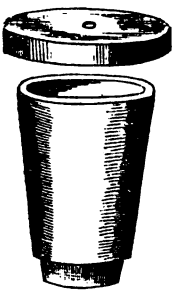
consequence of the close texture of the vessels, they do not differ so much when weighed in a dry and a damp state, as do the more porous English crucibles. The price in Glasgow of the smallest crucible and cover, as represented at the bottom of the preceding page, is 9d., that of the large crucible is 1s. 3d.

The chief use of these crucibles is in the ignition of metallic oxides, which are easily reducible in connection with metallic platinum; in the fusion of metallic oxides with sulphurets; in charring organic matter mixed with reducible metals, &c.

When a still larger glazed crucible is required, the porcelain mattrass represented at page 13, may be employed.

Another description of Berlin porcelain crucible is represented in the following figure. It is made of unglazed porcelain, and is furnished with a cover having a hole in the centre, intended to permit the escape of the gas generated in some processes. There are two sizes, provided with covers:—



No. 1, 2¼ inches high, 1¼ inches wide, price 8d
2, 3¼ do. 2 do. price 9d

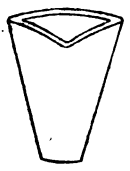
A larger size, 5 by 3½ inches, can also be had without cover. The price of this is 1s. 6d. The use of this variety of crucible is in fusing such substances as nitrate of silver. The crucible is not exposed to a free fire, but is placed within a common earthen crucible.

Small glazed porcelain pots, useful as crucibles in some inexact operations, may be had of the capacity of ¼ oz., and ½ oz., at the price of 2d. each. They are too thick to be generally useful.

Hessian Crucibles.—These are a species of clay crucibles that surpass most other substances in their power of resisting great heat, and the action of the substances used as fluxes. They are sold in nests at about the following prices:—

Nest of 3 –2 to 3 inches high, per nest, 4d.
——— 5–1 to 4 do. do. 8d.
——— 5—2 to 5 do. do. 10d.

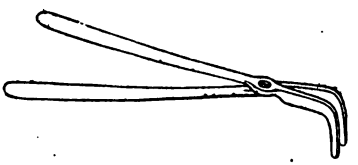
They are of a triangular form, without covers, of a dirty brown colour, and very rough surface. They are of but little use to a student of chemistry, who is provided with porcelain and platinum vessels. They are principally employed with furnaces, in the reduction and fusion of metals, and in some other operations not requiring great nicety, or not admitting of the presence of platinum. They require to be both heated and cooled very slowly, else they are liable to crack. Indeed, the reason why clay crucibles, which are so very cheap, are not more extensively used, is that they break too readily, and are too readily attacked



by almost everything that is melted in them. The consequence of which is, that they never can be used for a second operation, even when they escape whole from the first, although this is nearly impossible, unless the fire in the furnace be suffered to die out, and the crucible and furnace get gradually cool together.

GRAPHITE CRUCIBLES.—*Blue Pots.*—These suffer a very high temperature, and are not so easily attacked by fluxes, nor so readily cracked on cooling, as are the clay crucibles. They are liable to communicate both iron and charcoal to the substances that are fused in them. They cannot be used in the fusion of salts, which filter through their mass. They are of but little service to the chemical student. The price of one 3 inches high is 3d., 3½ inches high, 7d.

TONGS.—The best form of tongs for handling the platinum crucibles, is represented in the margin.



They should be of small size, and kept scrupulously clean, so as not to communicate any impurities to the matter contained in the crucibles which they are employed to remove. This form of tongs is not, however, so well adapted for the handling of crucibles that contain liquids, or of earthen crucibles, which are liable when seized by the edge to give way under the weight of any heavy charge that they may contain, and to leave in the tongs only the portion of the edge that they nip. Partly for this reason, and partly in order to avoid the chance of communicating extraneous matter by touching the inside of the crucible with a branch of the tongs, it is usual to remove earthen crucibles generally, and platinum crucibles which contain liquids, by tongs formed in the manner shown by the following figure.

GENERAL DIRECTIONS.—1. If a salt is to be deprived of its water of crystallisation, and the operation is not to be made with great exactness, the ignition may take place in the platinum spoon, or in the hemispherical platinum cup, or, for want of these, in a small porcelain cup. If greater exactness is required, a platinum crucible and cover should be used, and the ignition be assisted by the conical tin plate. The object of this precaution is, to expel a small portion of water which is found to adhere to some salts with great obstinacy. If you are desirous of ascertaining the proportion of the water to the dry residue, you first

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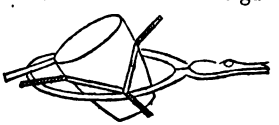
weigh the crucible and cover alone, then again with the crystals of salt within it, and finally after the ignition. The ignited salt should be weighed with the crucible and cover while still warm, but not until it can be handled by the fingers. The loss of weight occasioned by the ignition is the weight of the water expelled. The difference between the last weighing, and the weight of the crucible and cover only, is the weight of the anhydrous salt.

2. When a precipitate is to be ignited and weighed, it may be burnt with the filter, in a small platinum crucible, provided with a cover. The residue is to be weighed, as above; the crucible and cover are then to be cleaned, dried, and weighed apart. The difference shows the weight of the precipitate. Precipitates of chloride of silver are ignited and weighed in the small porcelain cup, page 98.

3. Sometimes it is necessary to provide the means of bringing a current of air into a crucible when undergoing ignition, for example, when organic matter is to be charred, converted into gas, and expelled. In the position in which a crucible is commonly placed over a lamp, and, as it is represented at page 19, it is surrounded on all sides by a current of air, extremely hot, indeed, but almost wholly deprived of oxygen, the force of which current rising continually, hinders the access of cold pure air. It necessarily follows, from the want of oxygen, that the organic matters in the crucible, though charred and intensely heated, cannot be converted into gases. To remedy this, you place the crucible upon a triangle, in the position shown in the margin, or fix it even a little farther out of the perpendicular than is here shown. You then place a slip of tin plate so as to rest partly on the iron ring of the retort stand, and partly within the crucible, bending the end that enters the crucible a little downwards. This metallic slip forms a sort of bridge, which permits atmospheric air to pass the current of hot gases, and enter into the crucible. This you can prove, by charring a bit of paper in the crucible. As soon as you place the bridge on, you will observe the coal of the paper to burn precisely as a dull coal fire does when subjected to the action of the bellows.



4. The crucible should, in all cases not otherwise directed, be no larger than is sufficient to hold the mass that is to be ignited; for a small crucible can be made hotter than a large one by the same flame. It should also, when not otherwise directed, always have the cover put on; for substances can be made hotter in a covered crucible than in an open one.

5. When a substance decrepitates, or when it is uncertain whether it decrepitates or not, it should invariably be heated in a closed crucible, or else be previously pulverized, in order to prevent decrepitation.

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Fusion.—The act of converting a solid into a fluid by means of heat. This operation is performed in the same vessels, in the same manner, and with the same precautions, as "Ignition."

Reduction.—The operation by which metals are restored to their metallic state, after having been deprived of it, by combination with some non-metallic substance. The metallic oxides, fulminating gold, horn silver, cinnabar, and other compounds of the same kind afford examples of reducible bodies. Reduction is also called *revivification*. The operation is performed in crucibles, by the aid of heat, and with the addition of certain substances, which act chemically upon the body to be reduced.

Fluxes are substances employed to assist the fusion of minerals, or the reduction of metallic oxides. *Crude flux* is a mixture of nitre and tartar, which is put into the crucible with the mineral intended to be fused. *White flux* is formed by projecting a mixture of equal parts of nitre and cream of tartar, by moderate portions at a time, into an ignited crucible. It is potash in tolerable purity. *Black flux* differs from white flux in the proportion of its ingredients. In this, the weight of the cream of tartar is double that of the nitre. The mixture for producing black flux may be ignited in the covered spoon, or one of the small porcelain pots or cups, or even in a common tobacco pipe.

Fusion and Reduction before the Blowpipe.—The reason that I have spoken in so summary a manner here, of the operations of fusion and reduction, is, that I purpose to describe circumstantially the method of fusing and reducing minute quantities of matter, when I come to speak of blowpipe apparatus, and of analysis by the blowpipe.

Ignition in Glass Tubes.—In qualitative analysis, the ignition of substances in glass tubes is a process of frequent occurrence; but as these ignitions are for the most part performed with the intent of producing Sublimation, I shall describe the mode of operating under that head.

SUBLIMATION.

Sublimation is a process, by which volatile substances are raised by heat, and again condensed in the solid form. The apparatus which it requires is very simple. Berzelius recommends the insertion of the lower end of a large platinum crucible into the mouth of a smaller one. The substance, upon being heated in the small crucible, condenses upon the under side of the large one, which should be filled with cold water. A similar arrangement, with cheaper vessels, is made by inserting a small glazed porcelain

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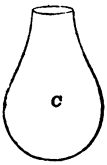
crucible, (No. 1, page 98) into the mouth of the larger glazed porcelain mattrass (page 13.) The substance to be sublimed is placed in the mattrass, and the crucible is filled with cold water, which is changed when it becomes warm. The sublimate condenses on the outside of the crucible, whence it is easy to be removed. It is sometimes sufficient to cover a small capsule with a large one, or with a cone of paper; while, in other cases, the vaporised body has to be conveyed into a flask by means of a conducting tube. An *alembic* is a flask with a wide mouth, such as is represented in the margin, *c*, and a capacious hollow stopple, or *head*, adapted to it. This vessel was formerly much employed in distillation and sublimation. The vaporised matter condenses in the head, whence, if liquid, it is permitted to run off by a spout.



SUBLIMATION IN GLASS TUBES.—In experiments undertaken to prove that a substance will sublime when heated in close vessels, or that, when it sublimes, it produces a particular kind of vapour, as respects its colour, or smell, or that it produces crystals; or in experiments made to ascertain whether a substance is volatile or not, or whether or not it can be converted into a volatile substance; in these, and many other cases of sublimation, it is now common to use no other apparatus than a glass tube closed at one end, and formed like one or other of the figures on the next page.

The substance to be sublimed is placed at the bottom of one of those tubes, and is then submitted to heat. The sublimate, if any is produced, condenses upon the upper part of the tube, and is there examined.

A very particular account of the results obtained by operating with these small vessels, and of the merits of the different shapes will be given in the articles "Arsenic," "Analysis by the Blowpipe," &c. in succeeding sections. What I have principally to do here, is to direct your attention to some general points of manipulation relative to sublimation in tubes.

(*a*) *Quality of the Tubes.*—The glass should be thin in substance, and free from lead. White glass made with potash is best, next to which is pale blueish green glass. Flint glass, containing lead, is objectionable for several reasons:—First, it melts at a lower temperature than that which several substances require for sublimation; secondly, it is readily decomposed by the flame employed to heat it, the combustible gases which accompany the flame absorb oxygen from the glass, and produce a film of metallic lead, which interferes with the observation of the sublimation within the tube; lastly, one of the most important of the substances which are examined in tubes of this sort, namely, arsenic, happens to require so high a temperature for its sublimation, that flint glass is almost invariably decomposed during the operation. The consequence of which is, that the operator is uncertain

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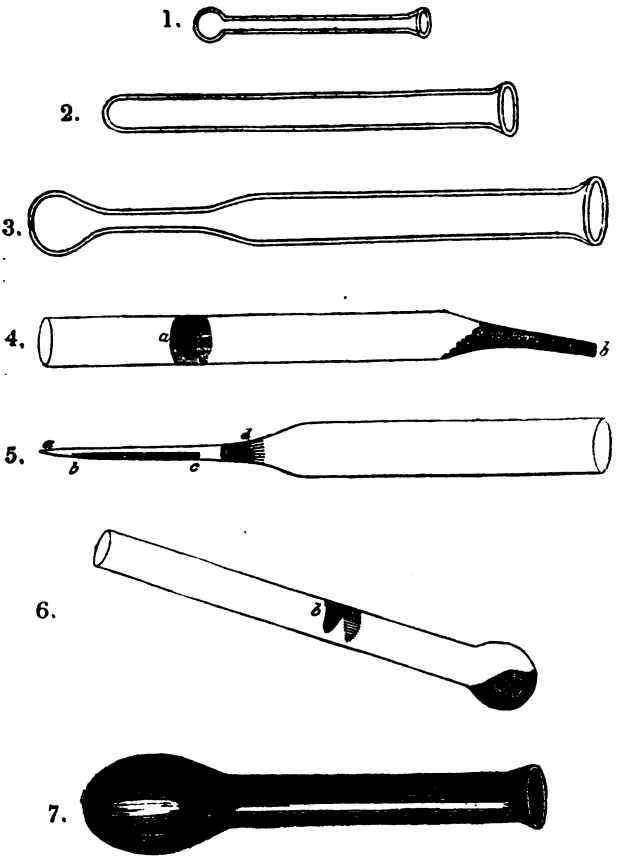

when he perceives a metallic film on the glass, whether he is to attribute it to arsenic or to lead.

Consequently, flint glass, which is known by its heaviness, its easy fusibility in the oxidating flame of the blowpipe, and its equally easy decomposition, (manifested by the appearance of a black film of metallic lead,) in the reducing flame of the blowpipe, is to be rejected in choosing or making glass tubes for sublimation. The best sort of glass for operations of this character is the hard white glass which is made in Bohemia.

(*b*) *Preparation of the Tubes.*—They must be *cleaned.* Tow, blotting paper, or a bit of soft silk handkerchief, introduced and

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turned about by a wire or a slip of whalebone, mostly answer the purpose. They must be *dried*. You warm them and suck air through them. See page 90.

(*c*) *Bulk of the Charge.*—This is regulated by a variety of circumstances. In experiments upon Arsenic, the quantity submitted to examination is frequently but a small portion of a grain. In miscellaneous experiments, such as those of determining whether or not a substance is volatile, or gives off water, or acid, &c., the quantity of matter need not in general be more than will lie upon the circle in the margin.

(*d*) *Insertion of the Charge.*—The substance which is to be submitted to sublimation requires to be conveyed to the *bottom* of the tube without soiling its *sides*. If the tube is more than a quarter of an inch in diameter, the substance, previously powdered and mixed with its flux, if any is requisite, can be inserted by means of a gutter of glazed post paper, in the manner described at page 15. If the tube is less than a quarter of an inch in diameter, such a method of inserting the charge is not easy. For example, it is impossible to convey a charge by means of a gutter of paper into the bulb of the third tube figured p. 104, without soiling the narrow neck that leads to the bulb. In these cases, the charge is to be first pushed down into its place by a platinum wire, or a bit of stick, and the tube is to be cleaned afterwards, while held in a vertical position, so as not to displace the charge. The cleaning is to be effected by means of the articles named above, or when the tube is too narrow to admit of these, by means of a needle and thread. The thread is put through the eye of the needle, and afterwards coiled round it, like the threads of a screw. You hold the needle by the point, and clean the tube by rubbing it with the thread wound round the other end of the needle.

(*e*) *Use of Test Papers.*—When the disengagement of ammonia, or of acid vapours, is anticipated, it is necessary to prepare the tube with test papers. If ammonia is expected, red litmus, turmeric, or cudbear is to be chosen. If an acid is anticipated, blue litmus is to be used, except in testing for hydrofluoric acid, which requires Brazil wood paper. The test paper must be folded or cut narrow enough to go into the tube; it must be moistened with pure water before it is inserted, because dry gases do not act upon dry test papers; and the end of the paper must project from the tube, and be turned over the edge, to prevent its slipping too far in and becoming burned. When it is uncertain what sort of vapour will be disengaged during the process, a slip of turmeric, and another of blue litmus, may be put in side by side, so as to detect either acid or alcali.

When water sublimes and condenses in the upper part of the tube, the test papers are employed to ascertain whether the water is acid, alcaline, or neutral.

Leaves of the little test books, represented at page 47, are very convenient for this use.

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(*f*) *Supports for the Tube in the Flame.*—The finger and thumb—rarely any thing else, except when you perform sublimation in a tube for the purpose of *preparing a quantity* of a sublimate, and not simply to ascertain the *fact* of sublimation, or the *nature* of the *sublimate*.

(*g*) *Exposure of the Tube to the Flame.*—The tube is first gently warmed all over by waving it at a distance above the flame of the spirit lamp. It is then brought close to the flame, and finally, the bottom where the charge is placed is held in the hottest part of the flame. The *position* of the tube may range from the horizontal to the vertical. The greater the heat that the substance requires to volatile it, the more upright must the tube be held; and when the substance is one that rises, like water, at a low heat, the tube must approach the horizontal position. It is advisable to begin by holding the tube nearly horizontally. If the substance rises, it is well. If not, the tube may be raised. Were you to reverse this arrangement, and to begin by holding the tube in a nearly vertical position, then if water were produced, it would run down from the cold to the hot part of the tube and crack it. If you happen to know the nature of the charge, then it is advisable to hold the tube vertically in subliming a compound of difficult sublimation, such as calomel, arsenic, or sulphuret of mercury; and horizontally in subliming iodine, camphor, corrosive sublimate, and others of more ready volatility. In the event of no action taking place after a tube has been for a few minutes exposed to the strongest heat of the spirit flame, it becomes necessary to urge the flame with the blowpipe.

(*h*) *Preparation of Sublimates in Tubes.*—In the case alluded to at (*f*), of subliming in quantity, the tube is commonly taken of a large size, and may be supported by the tube holder described at page 43. A short wide tube may be placed over the mouth of the subliming tube, to prevent the escape of the vapours; and the condensation may sometimes be facilitated by the application of wet blotting paper or tow to the upper part of the tube.

(*i*) *In what cases Tubes with Bulbs are most useful.*—When a substance is to be tested for water, or other incombustible volatile compounds, a bulb tube is to be employed, because the volatile matter rises most readily when the air has room to circulate in the vessel. When, on the other hand, you have to sublime combustible substances, such as arsenic or sulphur, a narrow tube is required to prevent combustion.

EXERCISES AND CLASS EXPERIMENTS.

1. Spread a small quantity of grossly-powdered gum-benzoin on the bottom of a porcelain basin, invert over it a glass tumbler, and apply to it a gentle heat by means of the lamp-furnace: the gum will melt, and dense fumes will immediately rise from it and deposit themselves on the sides of the glass in beautiful silky crystals of benzoic acid.

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2. Take a large glass jar, containing at its top a sprig of rosemary or some such shrub, and invert it over a flat thick piece of heated iron on which coarse powder of gum-benzoin has just been spread—then, the benzoic acid which arises, as in the preceding experiment, will be deposited on the branches of the shrub, producing a singular and beautiful representation of hoar frost.

3. Sulphur may be distilled by sublimation, using a retort with a very short neck joined to a receiver. See the article "Distillation."

4. Powdered indigo, gently heated over the spirit lamp between two watch glasses or tin capsules, sublimes in very splendid copper-coloured crystals. The upper capsule should be cooled by the application of wet blotting paper.

5. Take two parts of marble, and one part of muriate of ammonia. Pulverise them separately, and mix the whole intimately together. Put the mixture into a Florence flask, and put the neck of the flask through a cork into a receiver or large tube. Heat the flask by a lamp, and cool the receiver by wet paper. Carbonate of ammonia will sublime and condense in the solid state in the receiver.

6. Put a little camphor on a tin plate. Invert a conical test glass over it. Apply the heat of a spirit lamp below. The camphor readily sublimes.

7. Put a grain of iodine into a small flask, or glass tube, and apply heat. Splendid violet vapours of iodine soon fill the tube. When the sublimation of iodine is effected slowly, crystals are formed.

8. Sublime a grain of cinnabar in a tube one-third of an inch wide.

9. Sublime a grain of calomel in a similar tube. These two mercurial compounds will be found to be less easily volatilized than camphor, iodine, benzoic acid, and some other substances.

10. Put a grain of red oxide of mercury into a very small glass tube, and apply heat till the red oxide is entirely volatilized. Metallic mercury will condense on the sides of the tube, and oxygen gas escape at the mouth.

USE OF THE BLOWPIPE.

In many experiments, it is of great importance to be able to expose small substances to a very high temperature. For this, it is necessary to employ the *blowpipe*, an instrument with which a current of air is blown into the flame of a lamp or candle, so as to give one the power of producing in a moment, the most intense heat of a powerful furnace. You can easily perform, with the help of this little instrument, the experiments which are necessary to determine the chemical nature of many different substances. You can produce any temperature up to a white heat, and direct the hot flame upon any substance you wish.—Many advantages are derived from the use of the blowpipe. Its smallness and cheapness are no inconsiderable recommendations. The most expensive materials, and the

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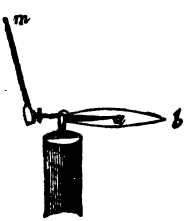
minutest specimens of bodies, may be used in these experiments; and the whole process, instead of being carried on in an opaque vessel, is under the eye of the observer from beginning to end. It is true, that very little can be determined in this way concerning the *quantities* of products; but in most cases, a knowledge of the *components* of any object is a great acquisition, which knowledge is thus obtained in a very short time, and serves, at all events, to show the best and least expensive way of conducting processes with the same matters, in the larger way.

DESCRIPTION OF THE BLOWPIPE.

THE blowpipe is a tube of brass, about seven inches long, and one-fourth of an inch in diameter at one end. It tapers off to a fine point at the other end, where the orifice is about the eightieth part of an inch in diameter. This point is bent on one side, and the tube is furnished with a cylindrical reservoir to hold the water which air, blown from the mouth, deposits in the tube. In using the blowpipe, the open end of the long tube is put into the mouth, the instrument being held in the right hand. Air in a continuous current is then gently blown through the tube, the narrow point of which is held against the side of the flame of a candle. Thereupon the upright flame of the candle is thrown into a horizontal or even into a descending direction, and at the same time is diminished in bulk and greatly increased in its power of ignition. The substance which is to be heated is supported by instruments held in the left hand, and is immersed in the deflected flame of the candle, which is called the blowpipe flame. In looking at the figure, you are to suppose the point *m* to be in the mouth of an operator placed opposite to yourself.



If you do not possess a blowpipe of the above form, you may employ a common brass goldsmith's blowpipe, which costs sixpence; but it is much more convenient to have a blowpipe with a reservoir, for the common sorts are very inconvenient. A good and cheap blowpipe may be prepared as follows:—Take a glass tube, eight inches long, three-eighths of an inch wide, and one-twelfth of an inch thick in the glass; bend an inch of it at one end at a right-angle, taking care to make the bend so carefully as not to obliterate the bore of the tube. The heat of a spirit lamp is sufficient to soften the glass that is to be bent. Next, take a piece of tube, two inches long, one-fourth of an inch thick, and one-twelfth of an inch in the bore; hold the point in the flame of a spirit lamp, continually turning round the tube, until the opening is contracted to a hole sufficiently small for the orifice of a blowpipe; bend this small tube at a right angle in the middle, and adapt the other end of it, by means of a cork,

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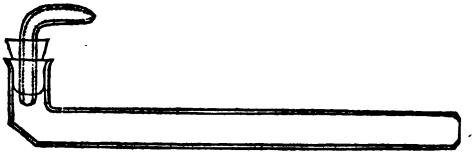
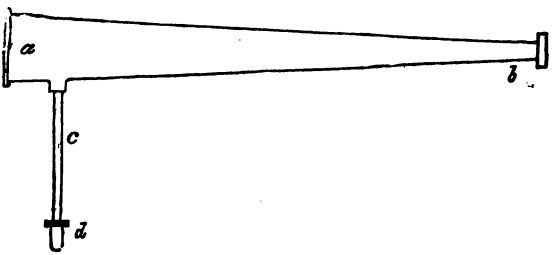


to the bent end of the larger tube. The point should be withdrawn from the flame and suffered to cool very gradually, that it may be well annealed. It is otherwise liable to split when presented to the flame afterwards as a blowpipe. This is the best of all the varieties of glass blowpipes. No water escapes from the jet. New jets are easily made when required, without the assistance of a glass blower. And the form and movements of the jet are such as to allow the blowpipe flame to be directed in any direction that may be required.

All the above varieties of the blowpipe are, however, greatly inferior to that which I shall describe next, a variety which, being very simple in its construction, not easy to put out of order, effectual in use, convenient to handle, and very low in price, possesses the advantages of most other blowpipes combined.

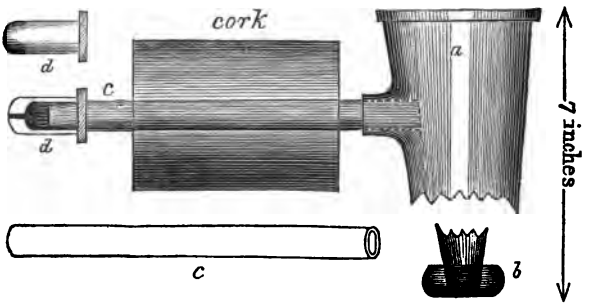


a, *b*, is a conical tube of japanned tin plate, $\frac{4}{5}$ of an inch wide at the broad end, and $\frac{1}{5}$ of an inch wide at the narrow end, which is surrounded by a ring of solder that forms a knob or button $\frac{2}{5}$ of an inch in external diameter. The narrow end of the tube is open, the wide end is closed. *c* is a brass pipe, 2 inches long, and $\frac{1}{8}$ of an inch in diameter, adapted by grinding to a socket that is soldered into the side of the conical tube near its broad end. *d* is a brass tube or cap, $\frac{1}{8}$ of an inch long, fitted by grinding upon the point of the tube *c*, and having at its other end an orifice of about the eightieth of an inch in diameter. All the joints of the instrument are made air tight, so that when air is blown in at the narrow end of the tube *b*, it can only issue forth at the small orifice in the jet *d*.

The length of the conical tube should be about seven inches.

The reason that I say *about* seven inches is, that, in fact, the *proper length* depends upon the eye of the operator. A substance submitted to examination before the blowpipe, must, during the experiment, be placed at that distance from the operator's eye at which he has the most distinct vision. Consequently, the length of the blowpipe must be regulated by the strength or weakness of his sight. Those which are made for sale at my suggestion are seven inches long, and I find them to answer very well. But in Edinburgh they make blowpipes of the enormous length of ten inches, though I cannot conceive any purpose for which they can be employed, unless it be glass blowing. Every person must adapt his blowpipe as he would his spectacles, to suit his own sight. If he procures one of the blowpipes here described, and finds it to be too short, the knob of solder *b*, can be melted off, and be replaced by a lengthening mouth piece, made of tin plate, wood, ivory, or, what the owner can in general most readily himself adapt to the instrument, a bit of glass tube.

The essential parts of this blowpipe are represented in the following diagram *in their full size.* Nothing is omitted, excepting the middle part of the long tube. The bottom at the



mouth *b* is here shown distinctly. The use of it is to prevent the too ready flowing of moisture from the lips into the tube. The brass pipe *c* is shown apart (in outline), and also in its proper position. The socket by which it is connected with the main tube, is a brass tube of half an inch in length, soldered in such a manner to the main tube, that half its length is within, and the other half without the main tube. The use of this socket is to afford the opportunity of taking the blowpipe to pieces for *packing;* but when the blowpipe is not for a traveller's use, the socket may be dispensed with, and the pipe *c* be soldered to the main tube *a*, in place of the socket.

It is essential, in the construction of a good blowpipe, to fix the pipe *c* at right angles to the axis of the main tube *a b*. In giving this opinion, I cannot avoid referring to the description

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and figure of a blowpipe, given by a celebrated Edinburgh chemist, Dr D. B. Reid, *Rudiments of Chemistry*, page 90. He directs it to be made ten inches long, and represents the pipe *c* as branching out at an angle of 55° from the axis of the main tube, so as to point away from the operator. He dispenses with the nozzle *d*, and directs the orifice of the pipe *c* to be the 40th of an inch in diameter. I have seen a blowpipe made upon this plan, and lest any person should be misled by a public recommendation of them given by so celebrated a teacher as Dr Reid, I think it right to say, that such a blowpipe is wholly unfit for use in chemical analysis. Its defects are these:—1. It is heavy and awkward. The orifice is too large, and when it becomes stopped with dirt, it is, from want of the small nozzle *d*, difficult to clean. 2. It blows the flame in such a direction upon the substance which is exposed to its action, as to drive the *volatile products* of the operations effectually away from the operator's nose. Yet one of the principal reasons for using the blowpipe, is, that it produces several volatile products, the *odour* of which indicates the nature. I need only name the compounds of sulphur, arsenic, and selenium. 3. From the length of the instrument, and the direction of the smaller branch, it becomes necessary to hold the substance which is to be heated at such a distance from the eye, and in such a position in reference to the lamp, that it proves just as impossible to *see* the solid residue which the flame leaves behind, as it is to *smell* the volatile matter which it drives away.

I return to the description of a good blowpipe. The pipe *c* is terminated by the nozzle *d*, of which there are two figures, the lower one (that upon the pipe *c*) representing a section, the upper figure showing the outside of it. The parts are well proportioned, excepting that the orifice appears in the section larger than it ought to do. The proper diameter is the 80th of an inch. But I shall hereafter speak of the means of finding or making the proper sort of orifice.

There is fixed upon the pipe *c*, a round cork, three quarters of an inch wide, and one inch long. It must fit the pipe pretty tight, so as not readily to shift about. The pipe passes through the centre of the cork. The use of the cork will be explained presently. It answers best when it is slightly conical, with the broader end turned towards the nozzle *d*.

When the blowpipe is not in use, it should be hung on a nail fixed in the wall, the head of the nail passing between the cork and the main tube *a*. The moisture within the tube then escapes at the end *b*.

This blowpipe is sold in Glasgow for one shilling. I pass over every other sort without notice; for there is none better than this, though there are many twenty times dearer. It is commonly called Dr Black's blowpipe, but it was the invention of a German workman who lived in Glasgow. The instrument which Dr Black used, was made by Mr Crichton, the ther-

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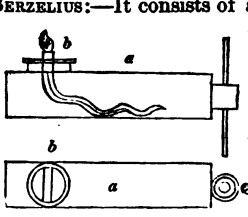
mometer maker, to whom Dr Black took the foreigner's blowpipe for a pattern. Mr Crichton always afterwards used a blowpipe of this description in blowing the bulbs of his thermometers.

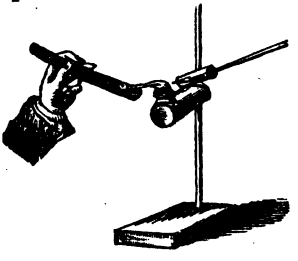
THE PROPER KIND OF COMBUSTIBLE FOR THE FLAME.

A CANDLE with a thick wick may be occasionally employed, but it is by no means a convenient or a profitable combustible. It does not always give a sufficient heat, and is besides subject to the inconvenience of being melted by the radiant heat from the substance under examination.

When a candle is used, it should be snuffed rather short, and the wick turned on one side towards the object, so that a part of it may lie horizontally. The stream of air from the blowpipe must be blown along this horizontal part, as near as may be without striking the wick. If the flame be ragged and irregular, it is a proof that the aperture of the nozzle is not round or smooth; and if the flame have a cavity through it, the aperture is too large. When the hole is of a proper figure and duly proportioned, the flame consists of a neat luminous blue cone, surrounded by another flame of a more faint and indistinct appearance. The strongest heat is at the point of the inner flame, or between *a* and *b*, in the figure on page 108.

OIL.—Next to gas, of which I shall speak presently, the best thing to use as a combustible for the blowpipe flame, is SWEET OIL, or DROPPINGS OF SWEET OIL, burnt in a lamp of the following description, which is the blowpipe lamp recommended by BERZELIUS:—It consists of a tin plate cylinder, one inch wide, and four inches long *(a)*. At *b* is a wick holder, three quarters of an inch across, for holding a flat lamp wick. This opening can be closed by a screw cap. *c* represents a little cylinder, fastened to the end of the lamp. This cylinder holds a perforated cork, which admits the rod *(d)* of a little retort stand, (such as is represented at page 36.) The lamp can be raised on this rod to any height the operator finds convenient.—The stream of air is blown along the top of the flat wick, and not across it. The flame is powerful, and at the same time much under the command of the operator.





The subjoined cut explains the method of supporting the lamp upon its stand, and the relative positions of the blowpipe and subject of experiments when in action.

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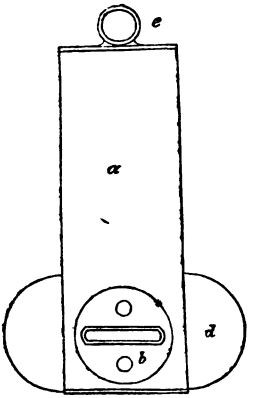
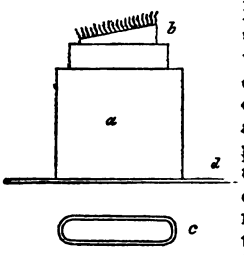
I shall here add a description of a blowpipe lamp, which I have somewhat altered from that of Berzelius, and which is now made for sale in Glasgow at a cheap rate, (the price of it is eighteen pence.) The body of the lamp is like that of Berzelius, of the oblong form, but its cross section is a square instead of a circle. It is made of tin plate and japanned. The annexed figures represent a view from above, and a view of the fore end.—*a* represents the body of the lamp, which is $3\frac{1}{2}$ inches long, and $1\frac{1}{4}$ inch square. *b* is the wick holder, which, as shown in the elevation, is cut aslant at top, so that the surface forms an angle of about 30°, with the top of the lamp. The lowest end of the top of the wick holder rises a little way above the neck of the lamp, which is $\frac{1}{4}$ inch high. The size of the orifice of the wick holder is shown by the third figure *c*. An oval piece of tin plate, $2\frac{1}{2}$ inches long, and $1\frac{1}{2}$ inch broad, is soldered across the bottom of the lamp immediately under the wick holder. The ends are shown at *d d*, producing a semi-circular projection on each side of the lamp, of about half an inch in width. The use of these projections is to support the hands of the operator during an experiment. At *e* is represented the tin cylinder, by means of which the lamp is held upon the rod of the retort stand. The cotton for this lamp can be purchased in long flat pieces, woven like tape, and, I believe, technically termed *half-inch cotton wick*. In trimming the lamp, take two pieces of this cotton wick, each six inches long, soak them 24 hours in strong vinegar, dry them before the fire, and put them smoothly and side by side through the wick holder. Preserve the stock of cotton wick, wrapped up in several folds of brown paper. It will not burn well if left carelessly about in dirty corners. When the light is extinguished after use, the charred wick should be immediately cut off by scissors level with the diagonal surface of the top of the wick holder, so as always to leave the wick in a state fit for use. There must never be any charcoal on the wick when in use, nor any ragged edges or loose threads. The wick must not be pulled too high out of the holder, otherwise it will smoke, nor must it be too short, otherwise it will give too little heat.





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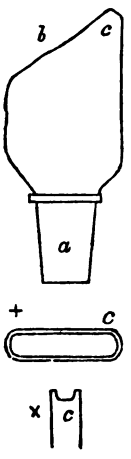
The lamp has a cover to put on over the wick and preserve it from dirt. But as the lamp is not intended for travelling, the cover is not made to screw on like that of BERZELIUS's lamp.



GAS.—If you can bring a gas light to the table where you are accustomed to perform chemical experiments, you need seek for no other flame for the use of the blowpipe. Yet its *convenient* use requires a little management, for the "single jet" or burner with one small orifice, furnished to the consumer of gas by the gas company, while it affords a sufficient flame for blowpipe use, only does so when under a pressure which sends the gas out with too great a velocity to be properly deflected by the blast from that instrument.

This inconvenience is obviated by the employment of a burner of the form and size figured in the margin. *a b c* is a front view of the burner. The neck, *a*, is exactly similar to the neck of the "single jet burners" of the gas company, and of course is adapted to fit the nozzles of all common gas pipes. Above this neck is a flat pipe, terminating in an orifice of the size shown by the second figure, + *c*. The top of this pipe is cut aslant at an angle of 40° from the horizontal, as shown by *b c* in the upper figure. A slight hollow is made at each end of the orifice, as shown at x *c*. When the burner is used for chemical experiments, it is placed in the position here represented, with the high corner to the right hand, and the stop cock is opened till the gas flame, when not acted upon by the blowpipe, gives about as much light as a tallow candle of six to the pound. When used for glass blowing, the burner is turned half round, so that the end, *c*, is placed farthest from the operator. The flame is then to be increased in size, by turning the stop cock as far as is found to be necessary.

The form of burner best adapted to render gas of use in blowpipe operations was determined by a set of experiments made by Professor CLARK of Aberdeen and myself, with that view. We procured burners with orifices of different forms, and fixed them upon gas pipes where they could be turned round horizontally and vertically. We thus produced a great variety of different gas flames, from which we selected the flame that could be most effectively acted upon by the blowpipe, and at the same time be kept under the most complete control.

HOW TO PRODUCE THE BLAST OF AIR.

WHEN you are going to operate, you sit with the lighted lamp before you, and nearly level with your mouth. You hold the blowpipe in your right hand, and putting the upper end into

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your mouth, you approach the point to the flame of the lamp, and blow gently through the tube so as to keep the flame continually deflected.

There is an artifice in the blowing through this pipe, which is more difficult to describe than to acquire. The effect intended to be produced is a continual stream of air for many minutes, if necessary, without ceasing. This is done by applying the tongue to the roof of the mouth, so as to interrupt the communication between the mouth and the passage of the nostrils; by which means the operator is at liberty to breathe through the nostrils, at the same time that, by the muscles of the lips and cheeks, he forces a continual stream of air from the anterior part of the mouth through the blowpipe. When the mouth begins to be empty, it is replenished by the lungs in an instant, while the tongue is withdrawn from the roof of the mouth, and replaced again in the same manner as in pronouncing the monosyllable *tut*. In this way the stream may be continued for a long time without any fatigue, if the flame be not urged too impetuously, and even in this case, no other fatigue is felt than that of the muscles of the lips.

I. The first thing that a beginner has to do is to accustom himself to breathe freely through the nostrils while his lips are kept firmly closed. II. This being effected, he should fill his mouth with air, by allowing his cheeks to distend as the air arrives through the posterior nostrils. III. He should then make two or three moderate inspirations and expirations by the nostrils, without opening his lips, or suffering the air to escape from his mouth. All this may be learnt with a very little practice. IV. When the learner has effected this much, he should introduce, between his lips the button, or mouth piece of the blowpipe, and then, having filled his mouth with air, he should force it through the blowpipe against the flame of the lamp, by the action of the muscles of the cheeks, while he continues to breathe without interruption through the nostrils. To some persons this is difficult, but frequent trials soon establish the habit of producing a continuous blast. It is like the difficulty of turning round the right arm and right leg in contrary directions at the same moment, which can be done after some practice.

HOW TO PRODUCE A STEADY JET OF FLAME.

HAVING, by the observance of the foregoing directions, accomplished the first object of keeping up a *steady blast*, the next thing to be attained is the power of producing a *steady jet of flame*. The latter cannot be produced without the former, but a steady blast may be blown without producing a steady flame, either from some defect in the lamp or in the orifice of the blowpipe, or from want of steadiness in the hand that holds the blowpipe.

DEFECTS IN THE LAMP.—1. Bad oil, such as fish oil, or even sweet oil that has remained long in the lamp and become thick.

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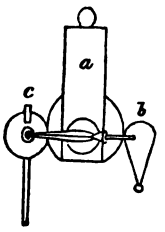
2. Dirty cotton, or an untrimmed wick. A pair of scissors and a pair of iron or brass pincers with fine points, should be in readiness to remove charcoal from the wick, and keep it clean and even. 3. A dirty wick holder. A common defect when the lamp has been some time out of use.—A clean lamp, clean cotton, and limpid oil, are indispensable requisites.

UNSTEADINESS OF HAND.—I have said that the blowpipe, is to be held in the right hand. To this I may add, that it is to be held by applying the thumb and forefinger of that hand to opposite sides of the cork which is fixed on the cross tube of the instrument. The thumb is to pass *below* the blowpipe, and the forefinger *above* it. The little finger of the same hand is to be lodged on *d*, the semi-circular platform affixed to the under side of the blowpipe lamp for this purpose. The second and third fingers are to be brought in between the cork and the little finger, so that the *upper side* of the first joint of the middle finger may press against the under side of the cork. The hand is thus half closed. If the point of the blowpipe is now held against the end of the wick, the relative positions of the blowpipe and lamp will be such as are shown in the marginal figure, where *a* is the lamp, *b* the blowpipe, somewhat foreshortened in the drawing, and *c* an object exposed to the blowpipe flame. If the operator has fixed his lamp firmly to its support, and placed it before him in the position formerly prescribed, the *steadiness* of the blowpipe is now put entirely under his controul.



DEFECTS IN THE ORIFICE OF THE BLOWPIPE.—They are as follows: too small a hole: too large a hole: a misshapen hole: stoppage by dirt.

In trying a blowpipe, you are to hold it in the manner just described, to enter the point of it the eighth of an inch into the flame, and the eighth of an inch above the wick, and to blow a current of air through the flame and parallel to the surface of the wick.

If the air deflects the whole mass of the lamp flame, and forms a horizontal blue cone of flame which converges to a blunt point at about an inch from the wick, with a larger, longer, and whiter flame enveloping the blue flame, and terminating at a point beyond the blunt point of the blue cone, then, the blowpipe is perfect.

If it produces a very small horizontal flame, and leaves the greater part of the lamp flame in its usual vertical position, the orifice of the blowpipe is too small, or is misshapen.

If it produces a large white rough-pointed flame, which makes a roaring noise, or if it throws out a large white unpointed flame, with apparently a hole through the middle of it, then the orifice of the blowpipe is too large.

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If it produces a blue cone of flame, with straggling white light on one side of it, the orifice is either dirty or out of shape.

To make an instrument for cleaning the orifice of a blowpipe, take a very small sewing needle, fix the head of it into a cork, to serve as a handle, and grind the sides of it for an inch from the point, upon a smooth stone, with oil, till you have converted it into a cutting tool with three edges, similar in shape to a triangular file. With this tool, you remove any dirt that may be in the orifice of the blowpipe, in which you turn it round very gently, so as not to cut the brass of which the nozzle is made.

But if the hole, after being cleaned by this means, proves, upon trial, to be still too small, the same instrument is employed to cut it larger. In this case you must be careful to insert the needle into the orifice through the inside of the nozzle, and not from without. If any burr or roughness is produced on the outer extremity of the orifice by this widening, it must be removed by a fine file. The hole must be quite round and quite smooth both within and on the external edge.

If the orifice is too large, the nozzle is to be placed with its open end, or milled rim, upon the face of a small anvil (page 4), and the point is to receive five or six gentle strokes with a hammer, which commonly bring the sides of the orifice closer together. If this does not suffice, a few gentle strokes may be given to the sides of the nozzle close to the orifice. It is necessary to make the hole rather smaller than is proper for use. The cutting tool is then inserted and turned round in the hole, and after suitable widening the burr is removed from the exterior by the file, in the manner already directed.

In the operation of *reduction* it is necessary, as will be explained in the next section, to have a blowpipe with a small orifice; while in the operation of *oxidation*, one with a large orifice is useful. It would therefore, apparently, be convenient to have two nozzles with orifices of different sizes adapted to the same blowpipe; but these operations frequently follow each other in such rapid succession that it is found to be inconvenient in practice to exchange the nozzles even when they are ready for use, and it is usual for the chemist to content himself with one nozzle only, and that with a small orifice, for it is much easier to oxidise with a small orifice than it is to reduce with a large one.

It will be readily inferred, from what has been said, that when the orifice of the blowpipe is misshapen, it must be treated as if it were too large, namely, it must be hammered together and opened anew.

As the triangular needle is often required for cleaning the blowpipe, I adapt its cork handle to the mouth of a small test tube, which thus becomes a case for it.

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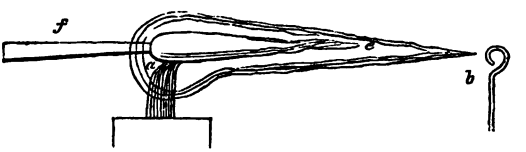
HOW TO EFFECT OXIDAION AND REDUCION.

When you have learned to produce a steady and continuous jet of flame, your next business is to study the properties of its different parts, and the means of employing or of modifying those properties. You have, for example, to learn which is the hottest part of the flame, which the part that is qualified to *communicate oxygen to a substance*, and which the part that serves best to *take oxygen away*, or to reduce a metallic oxide to the state of a metal.

The parts of a Vertical Flame.—Examine the flame of a candle attentively. You will perceive near the bottom a dark blue portion, *a c*, which gradually diminishes in size as it recedes from the wick, and disappears when it reaches the perpendicular side of the flame. In the midst of the flame, you observe a dark portion, *a d*, which is enveloped in a brighter shining portion of the flame. The dark part consists of combustible gases, as they rise from the wick, still unmixed with oxygen, and consequently unburned. Around the whole portions already mentioned, you will, on close examination, observe a thin coating of scarcely visible flame, *c e c*, which is largest at the apex *e*. It is in this outer coating that the mixture of the combustible gases with the oxygen of the air takes place—where in fact the *burning* is effected—and where you find the greatest heat of the flame. You can text this fact by the insertion of a fine iron wire.

The Oxidating Flame.—Put the point of the blowpipe about the tenth of an inch *into the flame*, and about as much *above the cotton*. Blow a current of air gently and steadily along the top



of the cotton, parallel to its surface, but without touching it. Blow strong enough to keep the flame straight in the direction of this blast, but be careful not to blow any stronger than is absolutely necessary for that purpose. Beginners commonly blow much too violently. Upon examining the blowpipe flame thus produced, you will observe a long blue cone, *a e*, converging to a blunt point at about an inch from the wick, and surrounded by an external flame, brownish, vague and indeter-

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mined in its form. The most intense degree of heat is at the point of the blue flame *e*, or between that point and the point of the outer flame. This point *e* is equivalent to the point *e* at the summit of the vertical flame, or rather to the surface *c e c* of the vertical flame; for, in the latter, oxygen being supplied to the combustible gases all round the flame, the heat resulting from the combustion is spread over a large surface; but in the blowpipe flame, active combustion takes place at a single central point in virtue of the oxygen forced into the middle of the flame by the blowpipe, and it is at that single point that the heat of the flame is concentrated. Hence, the blowpipe flame has the power to oxidise, reduce, melt, or vaporise, bodies upon which the vertical lamp flame is without action.

It is not, however, at the hottest part of the flame that the process of *oxidation* is effected. It is not indeed in the flame at all, but at the point *b* beyond it, where this phenomenon occurs; and the oxidation takes place the more readily, the further the combustible body is removed from the flame, provided always it be kept within reach of a sufficiently high temperature. You have, in performing this operation, to take care, as I before observed, not to blow too violently. If you force more air into the flame than it can consume, you afford a superfluous current of air, which is not required for the support or even the deflection of the flame, and which serves only to cool it. Too strong a blast is also injurious to the process of oxidation, especially when the assay is placed upon charcoal. In general, the operation goes on best when the substance to be oxidised is kept at a dull red heat,—when the blue cone is free from straggling rays of yellow flame,—when the blast is temperate,—and the blowpipe has a somewhat larger orifice than usual.

THE REDUCING FLAME.—In order to produce the oxidating flame, the blast is blown into the very centre of the vertical flame, which becomes in a manner turned inside out. On the contrary, the reducing flame is little more than a deflected vertical flame, if I may use so paradoxical an expression.

To produce the reducing flame, you must hold the blowpipe higher above the wick than you do to produce the oxidating flame, and you must not now allow the nozzle to enter so far into the flame. I shall presently sketch the position of the instrument in the margin. You should use the nozzle with a smaller orifice than is required to produce the oxidating flame, and, in this case, you should blow a little stronger than you need to do to produce the oxidating flame. The wick must be smooth cut, free from charcoal and loose threads. It must not be pulled up too high, otherwise the blowpipe flame will smoke; nor too low, otherwise the flame will be too small to answer the purpose of reduction. The blast must be continued for a considerable time without intermission, otherwise reduction cannot be effected. It is indeed chiefly for the purpose of performing this opera-

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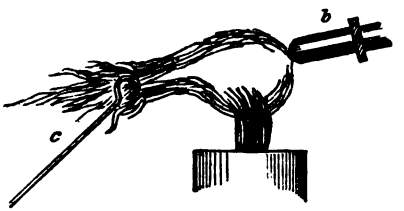
tion, that the power of keeping up a continuous blast is to be acquired.

The blue flame was formerly considered to be the reducing flame, but this is really not the case. It is the illuminating portion of the flame in which the reducing power exists. When the blowpipe is held in the position described above, the vertical flame is deflected entire and condensed into a small bright cylinder of fire, the point of which is surrounded by the same dimly visible portion of flame that is discernable as a fringe in the vertical flame. If this brilliant blowpipe flame, which is the reducing flame, is directed upon a bead of glass, fused on the end of a platinum wire *c*, and held at little more than half an inch from the lamp wick, the access of atmospheric air is completely cut off, and the bead is surrounded by the half-consumed combustible gases which compose the white flame. As these gases are strongly disposed to combine with oxygen, for the two reasons that they are very hot and that they are combustible, it is found that any oxidised substance present in the bead is very speedily deprived of a portion or of the whole of its oxygen, or it becomes what is technically termed *reduced*. So also when metallic oxides, supported on charcoal, are held in this flame, their reduction is effected with great rapidity, the operation being in this case facilitated by the reducing powers of the red-hot charcoal.



Substances that are easy of reduction can be reduced by the blue flame, if they are supported upon charcoal; but, in general, it is only the illuminating flame that acts as a reducing power. There is frequently some difficulty experienced by the learner in effecting the operation of reduction properly, but to effect oxidation is so easy that one need merely to be told how it is to be done, to be able immediately to do it. The power to produce at will either of these phenomena must be cultivated till it is acquired.

The oxidating flame is sometimes spoken of as the *outer* flame, and the reducing flame, as the *inner* flame.

MEANS OF SUPPORTING OBJECTS IN THE FLAME.

You examine, by means of the blowpipe, whether substances are volatile or not; whether they become decomposed by heat or not; what are the products of their decomposition; whether they are fusible or not; what phenomena they exhibit when fused with other substances; and how they act when heated so

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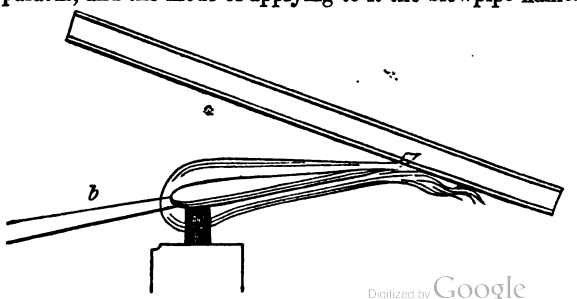
as to be oxidised or disoxidised. You must be provided, therefore, with means of supporting objects in the flame, which shall themselves be able to resist the action of the flame, which, for example, shall neither volatilise, nor fuse, nor become decomposed, nor oxidised. Unless the supports be of this kind, their power to support soon ends in their destruction. We are, however, unprovided with any one material of which to make supports adapted for all purposes. But we have the convenience of several materials adapted to different modes of experimenting, the most important of which are glass, charcoal, platinum, and copper.

Narrow Glass Tubes open at both ends.—There are experiments in which a substance is *roasted* (heated with free access of air) in order to ascertain if it is able to disengage certain descriptions of volatile matter. This operation is performed in glass tubes, open at both ends, and of about $\frac{1}{8}$ inch internal diameter. The sort of glass best fitted for this operation is hard white glass, made with potash, and free from lead. If this cannot be got, pale green glass is the next best material. Flint glass containing lead is wholly unfit for the purpose.

The substance to be examined is placed within the tube, and close to one end. The tube is then exposed to heat in an inclined position, with that end lowest where the assay is placed. According as more or less heat is required, the spot where the substance rests is heated by the flame either of the spirit lamp or the blowpipe. In general, it is best, first to apply the spirit lamp, and if the expected result is not then produced, to follow with the blowpipe flame. If the tube is held nearly horizontal, the current of air that passes through it is weak. If the tube is held in a nearly perpendicular position, the current of air is very strong. It is easy, therefore, to regulate the rapidity of the current according to the rate of oxidation that may be desired. The products of the combustion thus effected are either gases or sublimates. The method of discriminating them and ascertaining their nature will be explained in a subsequent chapter, on "Analysis by the Blowpipe." I subjoin a figure of this little apparatus, and the mode of applying to it the blowpipe flame.



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The length of the tube when first taken for this operation should be 6 or 7 inches. The ignition should take place at about half an inch from one end of it, and after every experiment, the portion where the assay has rested should be cut off with a file, and the remainder of the tube be cleaned for the next operation. To prevent the falling out of the subject of experiment when the tube is held vertically, it is best to bend the tube slightly at the point where the assay is to be placed, namely, at half an inch from the lower end.

GLASS TUBE CLOSED AT ONE END.—I have described this instrument under the head of "SUBLIMATION," page 103.

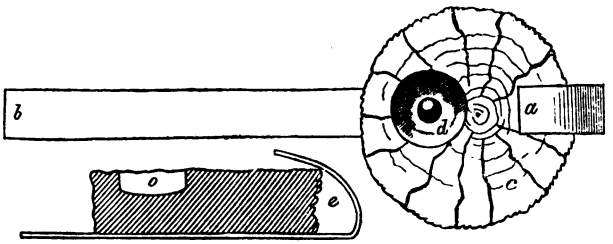
CHARCOAL.—The supports already described are of such a kind as serve to expose an object to heat, while they keep it out of immediate contact with the flame, enclosure being necessary for the retention of the volatile products of the *experiments*. But the support now under consideration is employed to present the assay directly to the action of the blowpipe flame, and with the freest access of air. The substance to be acted upon is simply laid upon the surface of a piece of charcoal and exposed to the blowpipe jet. Of course, volatile matter is in this case dispersed in the air, and is only capable of detection when it produces an *odour*, or when it deposits a *sublimate* upon the charcoal at a distance from the portion that is heated.

The charcoal should be well burnt and free from bark. It must not burn with flame, nor throw out sparks. Charcoal made from the wood of the pine, the willow, or the alder, is said by Berzelius and others to answer the purpose better than other descriptions of charcoal. Such varieties as contain much iron among their ashes must be avoided. For my own part, living generally in towns where I have no great choice of different woods, I take the charcoal that comes readiest to hand, and selecting the pieces that are well burnt, free from bark and crevices, and tolerably heavy, I find them generally to answer the purpose. In Glasgow, where charcoal is seldom used for fuel, it is often difficult to be procured. It is however a by-product of the manufacture of wood vinegar, and is thence obtained by the jewellers and other workmen by whom it is used in the arts. The charcoal produced in the distillation effected on Saturday, and which is permitted to cool slowly by remaining in the retorts till Monday morning, answers the purpose of a support in blowpipe operations much better than that which is drawn sooner from the retorts and cooled more rapidly in the open air.

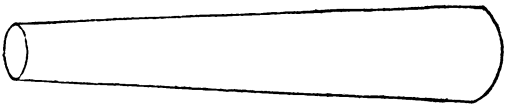
You prepare the charcoal for use as follows:—

Take sticks of an inch in diameter, or saw your charcoal, if it is in thick masses, into sticks an inch square. The most convenient size for the saw is one inch wide and nine inches long. My saw is a thin toothed flat steel blade of that size, without a handle.

Next saw these sticks crosswise, into flat pieces one third of an inch thick. The cut *c* represents the surface, and *o e* a section of one of the pieces thus produced. The radiating lines on figure *c*, represent the crevices in some sorts of charcoal. Such pieces are to be rejected as unfit for use. Every one of these plates of charcoal must have a small circular cavity on one side



similar to that represented at *d*, in the upper figure, and at *o* in the section. It must be the tenth of an inch deep, the fourth of an inch wide, and situate between the centre and the edge of one side of the plate of charcoal. This cavity is to serve as a species of capsule, to hold the substance that is to be heated before the blowpipe. The use of it is to prevent the matter from rolling off the charcoal, or from spreading too widely upon it, or from being blown away by the blast. To cut these cavities you must be provided with a *charcoal borer*, with which it is easy to sink a hole in the charcoal to any depth you require. This borer is a conical tube of tin plate, 2½ inches long, a



quarter of an inch wide at one end, and half an inch wide at the other end. Both extremities are filed on the outside till cutting edges are produced. The larger end of this instrument is used to produce cavities to hold bone ashes when the operation of cupellation is to be performed before the blowpipe. For an account of which operation, I refer you to the article "Analysis by the Blowpipe."

The plates of charcoal, having been formed and bored, are to be brushed from loose dust by means of a tooth brush or nail brush, and to be preserved in a box for use. You should never be without a supply. This method of making the charcoal into capsules for use, is not only more economical than that of using a large lump of it as a support, but in all cases is much more cleanly and convenient, and accompanied with far less risk of mixing and confusing the subjects and products of different experiments.

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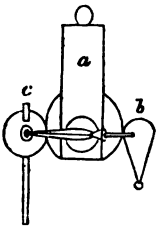
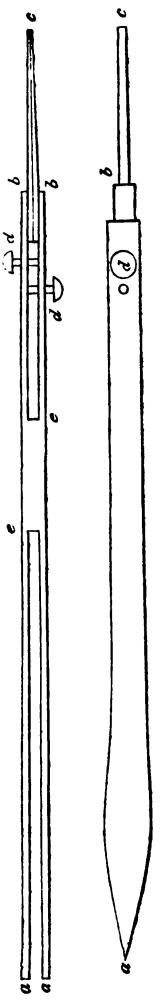
The charcoal capsules are too small to be held in the fire by the fingers. It is necessary, therefore, to fix them on a support, the most convenient material for which purpose I find to be a narrow and very thin slip of tin plate, of the size and form shown by *a b* in the figure on p. 123. The end of this slip is bent up into a sort of hook or clasp, *a*, *e*, and the plate of charcoal is pushed into the gap so formed. The tin plate must not be too thick, otherwise the elasticity of the bent part is not sufficient to secure the charcoal, nor its flexibility to enable it to suffer repeated bendings without breaking. The cut in the margin exhibits the position in which the charcoal plate is exposed to the blowpipe flame. The end of the tin slip is held by the thumb and two first fingers of the left hand, and the requisite steadiness is gained by resting the third finger upon the semicircular projection, *d*, on the left side of the lamp.



Platinum Tongs.—The platinum tongs are used to hold small splinters of minerals which are to be exposed to the blowpipe flame, in order that it may be known whether they are fusible or infusible. The tongs are also used in other experiments that will be described hereafter. The instrument is figured in the margin, both as seen in front and aside. The drawing shows the full size of the tongs. *a b* are two plates of hard steel, rivetted together in the middle to a piece of iron, *e e*. The points, *a a*, are hardened, so as to act as nippers, and are used to split small pieces from minerals for analysis. The points *b b* are rivetted to two slips of platinum, which need to be rather thicker and wider at the end *b* than is represented in the drawing. They taper off to a blunt point at *c*, not larger than is here depicted. The small iron block, *e e*, is usually made slightly wedge-shaped, and should have been so represented in the figure with its broad end towards *a a*. The object of this shape is to produce a spring sufficient to keep the points *c c* always shut when no other force



is in action. But to counteract this spring, and therefore to separate the points *c c* when necessary, the steel blades are furnished with two small knobs, *d d*, the pegs of which respectively, after passing through one of the steel blades, are fastened to the other. Hence when the finger and thumb are pressed upon the knobs *d d*, the platinum points *c c* separate, and when the pressure is removed, the points close and secure the object placed between them, in virtue of the spring produced by placing the two blades *a b* aslant upon the wedge *e e*. This pattern of blowpipe tongs is of French origin, and is much superior to all others that I have seen. It is the sort recommended by Berzelius. The price of it is from 6s. to 7s.

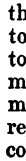
A Cheaper Variety of Platinum Tongs is made of two points of platinum of the size and thickness figured in the preceding page, and prepared by flattening platinum wire till it becomes as thin as a common playing card. These two points are rivetted to the two ends of an iron wire, the twelfth of an inch in thickness, and twelve inches long, bent into the form of a species of spring nippers. The instrument should be five inches long when complete.

The blowpipe tongs made in London, are generally of a clumsy form, and by no means so handy as the French pattern, while they are fully as dear. I have never met with any serviceable platinum tongs at a lower price than 6s.

Platinum Foil.—I have described this support in the article on "Sublimation," page 96.

Platinum Wire.—It should be of the length and thickness shown by the following figure. Such wires are sold in Glasgow

for twopence. This wire is used when the subject of experiment is to be fused with borax, to ascertain what coloured bead it produces with that flux. One end of it is bent into a hook, as represented above, or into a ring, as shown in the margin. In using this wire you are to proceed as follows:—



Moisten the hook with water or in your mouth, dip it into the pounded borax, and hold it with the borax that chances to adhere, in the blowpipe flame, until the borax is fused to a clear and colourless bead, that fills the hook. Next moisten the substance to be heated, fix it to the bead, and melt the two together in the oxidating flame, sustaining a regular blast till the mixture is thoroughly melted and incorporated, and there appears to be no further alteration produced by the flame. The fused mass is, in this state, in a good condition for undergoing examination. You can observe it both by transmitted and reflected light, and without any of the

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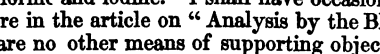
danger of mistake which arises from the play of false colour, that is so liable to perplex you when examining a coloured glass upon charcoal.

The glass bead, thus melted into the hook of the platinum wire, must, after examination, be removed, to permit the cleaning of the wire for a new experiment. If you attempt this removal by crushing the bead with the stroke of a hammer, you will often find the glass to be hard enough to cut the wire. It is better therefore to soak the bead in water, or in very dilute muriatic acid, and then to wash out the flux. This however requires time, and it becomes on this account necessary for you to provide yourself with two or three of these wires, that you may always have one in a fit state for use. If you should accidentally fuse on the wire, tin, lead, or any other substance capable of attacking it, a list of which substances I shall give under the head of "Platinum," there is no remedy but to cut off the end of the wire and bend a new hook. Accidents of this kind sometimes occur to the most cautious, and thus the wire is gradually shortened. When it is reduced to about an inch in length, and can no longer be held by the fingers, the point of it should be melted into the end of a piece of thermometer tube, which then serves as a handle, and enables you to use it till almost entirely exhausted. Even a bit of cork is sometimes useful as a handle for a short wire.

COPPER WIRE.—A very fine copper, or brass wire, of the following shape, is used in the blowpipe experiment for the detec-



tion of chlorine and iodine. I shall have occasion to speak fully of this wire in the article on "Analysis by the Blowpipe."

There are no other means of supporting objects in the blowpipe flame which are of sufficient importance to demand any particular description.

THE FLUXES USED WITH THE BLOWPIPE.

THE most important of the chemical compounds which are employed to facilitate the fusion, or to effect the decomposition, of substances heated before the blowpipe, are these three:—

1. BORAX,
2. CARBONATE OF SODA,
3. MICROCOSMIC SALT.

The chemical history of these substances, and the methods of preparing them, will be found in the article "Sodium." The mode of using them as fluxes in blowpipe operations, will be found in the article on "Analysis by the Blowpipe."

CHEMICAL PREPARATIONS REQUIRED IN A FEW PECULIAR BLOWPIPE EXPERIMENTS.—These are of far less *general use* than the fluxes

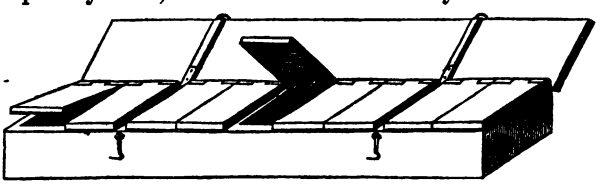
named above, but are, nevertheless, necessary to have at hand, to aid in the detection of particular elements.

1. Saltpetre, in small long crystals
2. Bisulphate of Potash, fused and powdered
3. Gypsum, water free, in small grains
4. Fluorspar, water free, in small grains
5. Nitrate of Cobalt, a strong solution in water
6. Oxalate of Nickel, in powder
7. Tin foil, cut into slips half an inch wide, and rolled hard up into little rods
8. Lead, in fine grains for cupellation
9. Bone ashes, for cupellation
10. Silica, in fine powder
11. Test papers in narrow slips
12. Formate of Soda.

The whole of these tests are, of course, to be provided in a state of purity. The method of using them I shall describe in speaking of the substances which they are employed to detect, in the article on "Analysis by the Blowpipe."

BOXES TO HOLD THE FLUXES.

In operating with the blowpipe, it is necessary to have always close at hand the various fluxes and tests enumerated in the preceding section, as well those required for particular operations as those of more general utility. When you begin to examine an unknown substance, it is impossible to foresee what your first experiments may indicate, and what particular mode of treatment you may be forced to adopt subsequently. Hence, it is proper to have ready for use whatever is likely to be in request, and as the substances employed in operations of this description are but few in number, and not of great bulk, it is easy to arrange the whole of them in a very small box. That which is exhibited in the following figure was contrived for this purpose by Gahn, and is now recommended by Berzelius. It



is a wooden box, 8½ inches long, 1¼ inch wide, and 1 inch deep. It contains 9 square cells, each provided with a separate cover, and the whole surmounted with a common cover, which can be secured, when closed, by a pair of hooks. The large cover is provided with brass hinges, but the small covers have wooden

hinges similar to those of the Scotch snuff boxes. All the covers require to be made so as to fit close and prevent the escape of the powders that are to be kept in them.

In some boxes the expense of these wooden hinges is obviated by the use of a fold of leather as a hinge.

Each re-agent that is much in use has a box to itself, but those which are used only in particular cases, are enclosed in paper, or small pill boxes, or short glass tubes, and packed several together in the remainder of the boxes. The boxes are sometimes stamped in front or on the lid with the names of the substances within them—as, BORAX—SODA—MIC-SALT—&c. The price of such a box, of polished wood, is in Glasgow, 12s.

SEFSTROEM has contrived a box of another kind for the travelling students of the School of Mines in Fahlun. This consists of a series of short bottles with wide mouths (such as Preston-salts bottles), closed with corks, each bottle and cork being labelled to correspond. As many bottles are provided as there are divisions in Gahn's box, and they are fitted stiffly into a box of japanned tin plate, which is made long and narrow to hold them in one row. The height of the sides of it is two-thirds the height of the bottles. The cover is in a separate piece, not fastened with hinges, but made to slip on like the cover of a tobacco box.

The vessels in which I keep the fluxes for my experiments, are small *snuff boxes* about 1½ inches long, and ½ inch deep, some of them made of wood, and others of papier machee. The covers are fastened on with hinges, they readily open and stand open. The names of the fluxes are written or painted on the top of each box. Being small and flat, they are easily ranged in any order I wish to put them. A few articles I keep in pill boxes and glass tubes, all labelled.

MISCELLANEOUS APPARATUS

Employed in Blowpipe Operations.

1. Hammer	5. Flat File	9. Washing Bottle
2. Anvil	6. Agate Mortar	10. Lucifer Matches
3. Knife	7. Microscope	11. Small Porcelain Capsules
4. Three-edged file	8. A Tray	12. Small Platinum Spatula.

THE hammer and anvil are for striking off bits of minerals for analysis, or for testing the malleability, &c. of metals. The knife is for mixing fluxes with powders preparatory to an operation. The mixture is kneaded in the palm of the left hand. A platinum spatula answers this purpose better than a knife. The latter, however, serves also to test the hardness of minerals. The three edged file is to cut glass tubes, or to try the hardness of minerals. The flat file is to file corks into shape, and sometimes to file metals. The agate mortar is to pulverise hard substances that require to be mingled and fused with fluxes. It is also in-

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dispensable to the success of the operation of reducing metallic oxides by means of soda. The microscope is to examine the results of experiments. It should be a single lens with strong magnifying power. The tray is to put below the lamp when you are working. The stone ware tray described in the section "Laboratory," answers the purpose very well. The bottom should be covered with a sheet of white paper, and it should be cleaned after every experiment. Its use is to catch and preserve in a clean state, the substance under examination, whenever it accidentally falls from the support. A tin tray, a sheet of paste board, or a large dish, serves the same use. Lucifers are to provide a light when necessary. The small porcelain capsules are useful to hold the substances that are prepared for examination. Sometimes they serve to evaporate small quantities of solutions produced in operations where acids are called in to aid the blowpipe.

Most of this miscellaneous apparatus is so fully described in other sections of this work, that it is unnecessary to dwell upon it in this place.

PROPER SIZE OF THE ASSAY.

The morsel submitted to experiment, is large enough when you can distinctly see the effect produced upon it. If the piece is too large, a part of it is necessarily out of the focus of the flame which is but a small point, and must then tend to cool not only the support, but the part of the assay which is immersed in the blue apex of the flame. The consequence of this is, that the heat is carried off as fast as it is produced, and you exhaust yourself before you effect the assay. You are much more likely in all cases, to fail in your experiment by using too large rather than too small a piece. The size generally recommended in books, is that of a pea, a pepper corn, a cube of the eighth of an inch, &c. is many times too large. A piece of the size of a grain of mustard seed is almost always sufficient. A small piece shows the same characters as a large piece, and an experiment upon it is made in less time, and with less fatigue. The size of a bead of borax or of microscopic salt should be this—O. The size of the mineral particle added to such a bead, should not exceed this—o.

A PROPER TABLE TO WORK AT.

The instruments used with the blowpipe ought to be so arranged as to be always at hand when required—all provided with places into which they can be readily put, and from which they can be promptly lifted. I shall describe the work table recommended by Gahn and Berzelius. The form of it is exhibited by the cut in the following page:—

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At each of the two ends there is a drawer, or tray, which can be pulled out, as is represented in the figure, so as to display its whole contents at once. These drawers are prevented from falling by fixture fillets of wood that run in grooves under the table top. The blowpipe apparatus and fluxes are arranged in these trays, the articles that are most frequently required being put into the right hand tray, and the other articles into the tray on the left hand. The divisions in the trays, as shown in the figure, are not fixtures, but consist of small boxes of tin plate, which are easier arranged, and are easier also to keep clean, than are cells made by fixed partitions.

The four drawers in front of the table are used to hold the lamp, the tin tray, a supply of charcoal, stock of fluxes, lamp wicks, substances intended for examination, and other bulky articles. A towel, often required in the course of working with the blowpipe, is hung to a small hook below the table, near to the operator's right hand.

Those who cannot get a table of the above description, or cannot provide a situation for such a table, may keep their apparatus for the blowpipe in a work box. This is the plan which I have followed for some time, and find to be convenient.

The box may be made of mahogany, or japanned tin plate. It should be eleven inches long, nine inches broad, and four inches deep. The cover should lift on and off, and be without hinges. There should be two trays exactly large enough to fit the box, yet so as to be easily put in or pulled out. They should both be an inch deep on the outside. Several small boxes, two inches deep on the outside, should be put into the bottom of the box. The two trays rest upon these boxes, and fill the large box to the top. The small deep boxes serve to hold the lamp, charcoal, supply of tubes, and all the larger articles. The

two upper trays are divided so as to hold all the small articles; the blowpipe, the three fluxes, the platinum supports, and the articles most frequently wanted being arranged in one tray, and the residue being packed into the second tray. During an experiment, the top of the box, inverted, supplies the place of the tin tray spoken of among the miscellaneous apparatus,—the box should be placed in front of the operator, the tray with the blowpipe on the right of the box, and the other tray on the opposite side. The whole Laboratory is thus laid open.

I pass now to the interpretation of the effects produced by blowpipe experiments.

ANALYSIS BY THE BLOWPIPE.

In the routine of Qualitative Analysis, the Blowpipe is extremely useful; for it resolves, with ease and precision, doubts respecting the presence of particular elements, which could only be otherwise determined by a tedious course of operations. It is impossible, however, except in the case of substances that have very few constituents, to effect qualitative analysis by the blowpipe *alone*. It must always be taken as subordinate or preliminary to liquid testing, or be exclusively applied to use, only when presenting facilities where liquid testing is not convenient. This facility of experimenting occurs, for example, in travelling, and now and then in chemical manufactories, where a question which has often to be decided is whether—among a variety of indifferent matters—some one *useful*, or at any rate, *interesting* substance is, or is not, to be found? This is a point which the blowpipe can often settle readier than any thing else. In such cases, therefore, this instrument comes into requisition.

The blowpipe experiments that give useful results, I shall here throw into such a *routine of operations* as appears to be best adapted to the detection of *all* the constituents of an unknown substance, when liquid testing is to be dispensed with, and the *blowpipe* to be used *alone*. But I do so without intending the pyrognostic assay to be held as any thing more than a course of experiments preparatory to liquid testing.

This routine is as follows:—

1st, The substance is heated in a small glass tube closed at one end.

2ndly, It is heated before the blowpipe in the open air.

3rdly, It is heated in a glass tube open at both ends.

4thly, It is heated with carbonate of soda.

5thly, It is fused with microcosmic salt.

6thly, It is fused with borax.

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The phenomena exhibited by a substance on exposure to these trials, afford data for a judgment on its chemical nature.

FIRST OPERATION.

HEAT THE SUBSTANCE IN A SMALL GLASS TUBE CLOSED AT ONE END.

METHOD.—The management of this operation has been described in the article on "Sublimation," page 103.

OBJECT OF THE OPERATION.—To ascertain what change is effected in the appearance of the substance; what sort of matter is disengaged—whether gas, liquid, or solid sublimate; whether or not decrepitation or phosphorescence takes place; whether the volatile products are acid, alcaline, or neutral.

If the substance chars or turns black, it may be presumed to contain vegetable or animal matter. If liquid is condensed on the upper part of the tube, the substance may be a hydrate or a salt with excess of volatile acid. If a powder appears on the side of the tube, it indicates the presence of volatile metals or oxides, or of sulphur or selenium. The metals are at once distinguished by their lustre; the other substances can be discriminated by their particular characters, as I shall show presently. The following is a list of substances that can be volatilised by this method.

A, Organic Bodies.
B, Water.
C, Volatile Acids, gaseous and liquid.
D, Sulphur.
E, Selenium.
F, Volatile Metals.
G, Volatile Oxides and Acids, of a solid form.
H, Volatile Saline bodies.

The characters of these substances I shall give individually, commencing by explaining more fully the inferences to be drawn upon seeing the subject of experiment *become black* when heated.

A, ORGANIC BODIES.

The first operation serves very well to indicate the presence of *organic substances*, when constituting or contained in the object of experiment, almost all of which substances, when heated in this manner, suffer decomposition, give off copious vapours, and leave a fixed residuum of charcoal. The volatile matters given off are water, acetic, and various other acids, empyreumatic oil, ammonia, carbonic acid, sometimes cyanogen, and other compounds, according to the nature of the particular organic body submitted to examination. But it is to the production in this experiment of *charcoal*, as serving to discriminate *organic* from *inorganic* bodies, that I am desirous of directing

your chief attention. The discrimination of organic substances *from one another*, is no part of the business now under consideration.[1, 2]

Many inorganic bodies also become black when heated in a glass tube, either in consequence of containing a slight intermixture of organic matter, or from some other accidental cause. The difference in appearance, however, between a blackened inorganic body, and a charred organic body, is very considerable; as, in case of doubt, you can prove comparatively by igniting a small portion of any organic substance in a separate tube. If, however, a comparative experiment of this kind does not satisfy you, the following more conclusive trial may be made:—Melt a little nitrate of potash in a porcelain cup over the spirit lamp, and throw a little of the unknown substance into the melted salt. Every organic substance, or nearly so, deflagrates when thus brought into contact with ignited saltpetre; and though some inorganic substances, such as sulphur and the sulphurets, do the same, yet carbonisation by heat, and deflagration with saltpetre, are characters that when taken together evidently denote an organic body.[3] If organic matter is found to be present in a state of admixture with the substance to be examined, it is advisable to get rid of the organic matter by combustion, before proceeding farther with the analysis; for the action of liquid tests on inorganic substances is materially altered by the presence of organic substances. With a view to effect this object, a small portion of the compound is first to be heated on *charcoal* before the blowpipe, in a manner to be hereafter described. The purpose of this preliminary experiment is to ascertain if the substance contains a metal easily reducible when heated with charcoal. If it does not, a portion of the

1. Roll up a small bit of paper, and heat it in a glass tube. A white fume is produced, which settles on the sides of the glass, as a brown-coloured oil, having a strong empyreumatic smell. Blue litmus paper turns red, and red turmeric paper turns yellow in the mouth of the tube, indicating the disengagement of a volatile acid. The paper heated in the tube turns black, but does not alter its form. On examination you will find it converted into charcoal.

2. In another glass tube, heat a single grain of cochineal. A similar white fume appears to that produced by the previous experiment, a similar burnt oil, and a similar conversion of the ignited substance into a mass of charcoal. But a more powerful and unpleasant odour is produced, and at the mouth of the tube red litmus paper turns blue, and yellow turmeric paper turns brown, changes that indicate the disengagement of ammoniacal vapours.

The first of these experiments shows the general character of vegetable bodies, the last shows the character of animal bodies.

3. Put two grains of nitre into a small porcelain cup, and place it on a triangle over a spirit lamp. When the nitre is melted, and become red hot, drop into it a little coarsely-pounded charcoal. An immediate deflagration takes place. This experiment can be made on a large scale by melting a quantity of nitre in a Florence flask, and pouring into it a stream of charcoal powder. The deflagration is superb.

The charred mass produced when organic bodies are burnt in glass tubes, deflagrates like charcoal, when thrown into red hot nitre.

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substance may then be ignited in a small platinum crucible over the large spirit lamp. The crucible is to be placed in a sloping position, the cover about three-fourths on, and a slip of iron is to be placed on the open part of the crucible, to produce within it a current of air. See page 101. The organic matter is thus both charred and consumed. If, however, the experiment on charcoal shows that easily reducible metals are present, then the platinum crucible cannot be used, and one of porcelain must be employed in its stead; but in this case the conversion of the charred organic matter into carbonic acid does not succeed nearly so well as it does in a platinum vessel.

B, WATER.

It may be present as combined water, or only held mechanically. The former is found in hydrates, crystallized salts, &c. The latter occurs in salts that decrepitate, and in all porous bodies. The water raised from these bodies in vapour, settles upon the sides of the upper part of the tube. If the quantity is considerable, it is held to be an essential constituent of the substance operated upon. While the tube is hot, it must be held in a position nearly horizontal, or rather with the mouth inclined downwards, lest the water run back to the hot part of the tube and crack it. You try, with test paper, whether the water is neutral, acid, or alcaline. The latter indicates the presence of ammonia. The tube should be warmed and dried immediately before the experiment.[4] [5] [6]

C, VOLATILE ACIDS, *Gaseous or Liquid.*

Super Salts, containing acids that are volatile, either when pure or when combined with water, give off, on being heated in this manner, their excess of acid; and if moistened litmus paper is previously put into the neck of the tube, it becomes reddened.[7] Some also of the *neutral* salts of these volatile acids are decomposed by this process. This is particularly the case with many *Nitrates*, the presence of which is indicated by the production of copious red fumes of nitrous acid gas.[8] The *Hyposulphates* also are decomposed, and give off sulphurous acid gas. And such *Fluorides* as contain water, are decomposed,

4. Take a small closed tube, dry it, insert a bit of charcoal as big as a pea, undried. Warm the tube over a lamp. Observe the deposition of water on the glass. Test with litmus paper, and find the water neutral.

5. Repeat the experiment with a small piece of hydrous gypsum.

6. Repeat it with a little crystallized sulphate of soda, or carbonate of soda.

7. Heat a small quantity of dry bisulphate of potash in a closed tube. Insert a slip of blue litmus paper. Observe that it becomes reddened.

8. Heat a little nitrate of lead in a closed tube. Observe the evolution of red fumes of nitrous acid gas, indicating the decomposition of a nitrate.

Repeat the experiment with nitrate of potash. Observe the fusion of the salt without decomposition, and consequently without evolution of the red fumes. It requires a much stronger heat to decompose the nitrates of the alcalies than those of the common metals.

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and give off hydrofluoric acid. This acid turns moistened brazil wood test paper yellow; but the experiment requires a strong red heat, and a hard glass tube.

Oxalic acid in a free state volatilises undecomposed; but the oxalates of fixed alcalies and of earths, give off carbonic oxide gas which can be ignited at the mouth of the tube, where it burns with a blue flame. Other oxalates give off carbonic acid gas, some with admixture of carbonic oxide gas. The fixed carbonate which remains behind is generally blackened by adhering charcoal. The *Cyanides* commonly are strongly charred, and disengage nitrogen gas, often accompanied by cyanogen, ammonia, and water. Dry cyanides of the metals of the alcalies and the earths are not decomposed by this process. Dry cyanide of silver or of mercury produces cyanogen gas and metal. The gas can be burned at the mouth of the tube, where it produces a blue flame.

D, SULPHUR.

Sulphur can be sublimed either from a substance containing it in mechanical admixture, or from such metallic sulphurets as suffer a partial desulphuration when exposed to heat in close vessels. Such are the higher sulphurets of iron (pyrites), copper, tin (aurum musivum), and antimony. Some other sulphurets give off small portions of sulphur, in consequence of a partial oxidation of their metallic base effected during the operation. The sulphur sublimes in drops, which are reddish-brown while hot, and yellow when cold. The hyposulphites also sublime sulphur.[9]

Only the *volatile* metals produce *volatile sulphurets*, and only the sulphurets of mercury and arsenic sublime undecomposed. The sublimate of the former is black, but becomes red if rubbed;[10] that of the latter is dark-yellow or red.[11. 12.] But the sulphuret of arsenic is apt to be mistaken for sulphur, and its discrimination requires a different experiment. See "Arsenic."

9. Put a small quantity of sulphur into a closed tube, and sublime it by the heat of the spirit lamp. Observe the appearances produced, the odour, and the action of the vapour upon blue litmus paper, that you may be prepared to recognise sulphur when you afterwards sublime it from an unknown substance.

10. Heat a little sulphuret of mercury in a closed tube. You will produce a sublimate. If the tube is very small, the sublimate will be black sulphuret of mercury. If the tube is so wide as to admit the circulation of atmospheric air, a partial decomposition is effected, and the sublimate is partly black sulphuret, and partly metallic mercury. Scratch out a little of the black sulphuret upon paper. Rub it, and observe that it becomes red.

11. Heat a little realgar in a closed tube. Observe the fusion and boiling, and then the formation of a sublimate in the form of crimson drops, which look like drops of blood, but which congeal to solid beads possessing the same crimson colour.

12 Heat orpiment in the same manner. Observe that the sublimate is in powder, part of it having a red-brown colour, and part of it a clear yellow colour, similar to the colour of pure sulphur.

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E, SELENIUM.

SELENIUM can be sublimed under the same circumstances as sulphur, either when present in admixture, or when contained in a state of superabundance in seleniurets. The sublimate, if small, is reddish, if large, it is black. If heated strongly in the open air, it produces a strong odour of decayed horse radish.

F, VOLATILE METALS.

THESE are arsenic, mercury, cadmium, and tellurium, which all possess metallic lustre, and a black or grey colour.

1. *Arsenic.*—It sublimes either from metallic arsenic, or from certain alloys of arsenic—such, namely, as contain a large proportion of arsenic, and are reducible by heat into alloys with a smaller proportion, and secondly, such as contain arsenic in a feeble state of combination. To the first variety belong arsenical nickel, arsenical cobalt, arsenical iron;[13, 14] to the latter belong the combinations of arsenic with antimony. A sublimate of arsenic is also given by some of the arsenites. The characteristic of arsenic in the state of vapour is its smell of garlic.

2. *Mercury.*—It is sublimed from most of its compounds and is more easily detected than any other metal. If the quantity of the sublimate is small, it has a grey earthy appearance; but friction with a glass rod unites the minute metallic particles into visible drops.[15]

3. *Cadmium.*—It is sublimed from some of its alloys. It is distinguished from other volatile metals by producing a *yellowish brown sublimate* of oxide of cadmium when heated upon charcoal in the open air: the sublimate falls on the charcoal around the assay.

4. *Tellurium.*—It is rather difficult of sublimation, and when the experiment is made in a small closed tube, the sublimate is only produced at a very strong red heat. It is deposited in small metallic drops on the cold part of the glass. The drops resemble those of mercury, but are solid.

13. Heat a little mispickel (arsenical iron) in a tube of hard glass made without lead. Increase the heat gradually, at last making it pretty strong. First, you will observe a red sublimate, which is sulphuret of arsenic. Afterwards you will see metallic arsenic on the tube. When you do see it, heat the part of the tube where the arsenic is deposited, and cause it to sublime. Then hold the mouth of the tube near your nose, and smell the odour of garlic by which the vapour of arsenic is recognised. Remember that this vapour is poisonous, and that it is not to be held near the nose a moment longer than is necessary to enable you to smell it.

14. Repeat the experiment in the smallest tube that you can procure, to ascertain upon what small quantities of arsenical compounds it is possible to work, without sacrificing accuracy in the results.

15. Heat very small quantities of red oxide of mercury in very narrow and short glass tubes closed at one end. Decomposition speedily takes place, Oxygen gas is expelled, and metallic mercury sublimed. Use at first one grain of the red oxide. Then repeat the experiment with smaller quantities, as with the half, fourth, tenth of a grain, and so on, in order to ascertain what is the smallest quantity with which you can obtain a satisfactory result.

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G, SOLID VOLATILE OXIDES AND ACIDS.

These are oxide of antimony, oxide of tellurium, arsenious acid, arsenic acid, and osmic acid.

1. *Oxide of Antimony* first fuses to a yellow liquid, and then sublimes in shining needles. Antimonious acid, which is often present in oxide of antimony, does not sublime.

2. *Oxide of Tellurium* behaves nearly like oxide of antimony, but does not give a *crystalline* sublimate.

3. *Arsenious Acid* sublimes very easily.[16] The sublimate consists of microscopic octahedral crystals. See the general article "Arsenic."

4. *Arsenic Acid* is decomposed by a strong heat, gives off oxygen gas, and produces a sublimate of arsenious acid.

5. *Osmic Acid* sublimes in white drops and forms crystal needles on the cold part of the glass. It has a strong and peculiar odour and acts upon the eyes.

H, VOLATILE SALINE BODIES.

These are the salts of ammonia, and the chlorides, iodides, and bromides of mercury.

Ammoniacal Salts.—They all sublime without residue, unless they contain a fixed acid, such as the phosphoric, or the boracic acid. They are then decomposed, and the acid remains behind. The disengaged ammonia is detected by its smell, or by its alcaline action on turmeric paper, or reddened litmus paper, placed in the tube.

The simplest way to test these salts, is to mix them on platinum foil, or in a small cup, with a little carbonate of soda and water, and to apply heat, whereupon ammonia is disengaged in abundance.[17]

Perchloride of Mercury (*corrosive sublimate*) at a very gentle heat, first fuses and then sublimes.

Protochloride of Mercury (*Calomel.*)—Sublimes without fusing. Its sublimate is yellowish while hot, but white when cold.[18]

Bromides and *Iodides* of mercury behave much like the chlorides. It merits remark, however, that the *red* iodide gives a *yellow* sublimate.

Such are the characters of the substances that can be volatilized by simple ignition.

16. Heat a very small quantity of arsenious acid (white oxide of arsenic) in a narrow glass tube. Observe the production of a white crystalline sublimate.

17. Mix in a small porcelain cup, or on a slip of platinum foil, a grain of any salt of ammonia with a grain of carbonate of soda and a drop of water. Apply a gentle heat. Gaseous ammonia is immediately disengaged. Smell it, or hold a slip of moistened test paper over the mixture. Or bring near it a glass rod dipped in muriatic acid. The red litmus turns blue, and the glass rod produces copious white fumes.

18. Heat a little calomel and a little corrosive sublimate in separate closed tubes. Observe the circumstances attending the sublimation of each substance as particularised in the text.

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The closed tube is also employed for the ignition of substances that *decrepitate*, and the warming of such as *phosphoresce*. The mineral called fluorspar exhibits both phenomena.[19. 20.]

VARIATIONS OF THE FIRST OPERATION.

A VARIETY of substances are heated in the closed tube in admixture with re-agents, which effect changes that heat alone is insufficient to effect. Thus:—

A, Mercury is detected by dried soda, by a method to be described presently.

B, Nitrates
C, Fluorides
D, Iodides
E, Bromides
} are detected by bisulphate of potash.

F, Sulphates of the common Metals, by charcoal powder.

A. MERCURY.—Both of the chlorides, and indeed all the compounds of mercury, if mixed with *dried carbonate of soda*, and heated in a closed tube, give a sublimate of metallic mercury. Whenever, therefore, a substance is suspected to contain mercury, it is mixed with an excess of soda, previously dried by ignition in a platinum spoon, or in a small porcelain cup, and the mixture, inserted in a tube, is heated, first by the mere flame of the spirit lamp, and then by the same flame urged with the blowpipe. If mercury is present, a grey coat of sublimed metal soon appears on the cold part of the tube. It sometimes, however, does not resemble metallic mercury, but the minute drops of metal can be easily collected into visible globules by friction with a glass rod or a bit of stick. If the compound contains water, or if *undried* soda is used, then water as well as mercury sublimes, and the water, readily forming into drops, is apt to run down to the hot part of the tube and crack it. To prevent this, the tube should be held as much as possible out of the perpendicular, or the water may be abstracted from the tube by inserting into it a small roll of blotting paper.

If the subject of experiment be extremely volatile, such as the chloride or bromide of mercury, it is possible to manage so ill as to drive off the whole of it in vapour before raising a sufficient heat to enable the soda to decompose it. In such a case no metallic mercury is got. This effect can be prevented by mixing the compound and the soda with water, and applying the heat pretty strong at first. You run the risk, however, of breaking the glass by this procedure.

19. Take a bit of fluorspar about half the size of a pea, and heat it in a glass tube having a bulb at the end. A very small blue flame answers best. The wick of the spirit lamp should be pushed almost close into the tube. A great many varieties of fluorspar, but not all, give, when thus heated, a pale purple lambent light, similar to that afforded by the slow spontaneous combustion of phosphorus. Upon raising the heat, decrepitation ensues.

20. Common salt treated in the same manner decrepitates, but does not phosphoresce.

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Another useful method of operating is to use a very narrow glass tube, to put the mercurial compound at the bottom, to put above it nearly an inch of dried carbonate of soda, to make the soda red hot by holding the tube horizontally across the spirit flame without heating the mercurial compound, and finally, when the soda is red hot, to incline the tube in such a manner as to bring the point of it where the mercurial compound is placed into the spirit flame without withdrawing the portion that contains the soda. The mercurial compound then sublimes through the red hot soda and becomes decomposed. [21] [22]

B, NITRATES.—When mingled with pounded bisulphate of potash, put into a glass tube, and heated in the flame of a spirit lamp, the nitrates disengage abundant vapours of nitrous acid. This is readily distinguished by its strong red colour and peculiar odour.[23]

C, FLUORIDES.—When mixed and ignited in a closed tube with bisulphate of potash, the fluorides disengage hydrofluoric acid, which corrodes the neck of the tube and makes it opaque, and changes red brazil wood paper to yellow. The tube requires to be cleaned before its loss of transparency can be ascertained.[24]

D, IODIDES.—When mixed and heated with bisulphate of potash, the iodides disengage iodine in vapour. Its violet colour is readily seen. It condenses into a black sublimate of iodine, and sulphurous acid escapes from the tube.[25]

E, BROMIDES.—When heated with bisulphate of potash, the bromides disengage sulphurous acid gas, and a little bromine gas, the colour of which is yellow; but it is *only* a little, and the experiment is scarcely to be depended upon as sufficient to determine the presence of bromine. The trial must be made by daylight.

F, SULPHATES.—Ignite the powdered sulphate in a silver or platinum spoon in order to drive off water; mix it with dry (ignited) charcoal powder, and ignite the mixture in a glass tube, using the blowpipe to strengthen the flame. There will be a strong

21. Examine experimentally these three methods. Take three small tubes and a quarter of a grain of corrosive sublimate to each. In the first, mix and heat the mercurial salt with dry carbonate of soda; in the second, with wet carbonate of soda; in the third, heat it with dry soda placed above it and ignited previously. Most probably, in all cases, you will obtain a sublimate composed partly of metallic mercury and partly of a white powder, consisting of undecomposed corrosive sublimate. The most successful experiment is that which affords the greatest quantity of metallic mercury.

22. Afterwards, take a little native cinnabar, or of factitious sulphuret of mercury, or of any salt of that metal; mix it with dry carbonate of soda, and ignite it in a very small closed glass tube. Observe the sublimation of metallic mercury.

23. Mix a grain of nitre with a grain of bisulphate of potash, and heat the mixture in a small closed glass tube. Observe the red fumes of nitrous acid.

24. Ignite pounded fluorspar with bisulphate of potash, and observe the reactions of hydrofluoric acid upon glass, and upon the colour of Brazil wood paper.

25. Mix a grain of iodide of lead with two grains of bisulphate of potash, and heat the mixture in a small closed tube. The splendid purple vapour of iodine is soon produced.

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disengagement of sulphurous acid, which is readily known by its odour, and by its ability to bleach moistened Brazil wood paper. This method of detecting sulphates applies, however, only to sulphates *of reducible metals*, and not to such as contain earths or alcalies.[26, 27]

ARSENIC.—It is by operations similar to those we are considering, that arsenic, in its metallic state, is frequently reduced from very small portions of arsenical compounds obtained in medico-legal investigations. This subject, however, will be fully treated of under the general head of "ARSENIC."

REDUCTIONS EFFECTED IN CLOSED TUBES BY MEANS OF FORMATE OF SODA.—When formate of soda is ignited, it gives off a large quantity of carbonic oxide gas. If the formate of soda, previous to its ignition, is mixed with a metallic oxide, or if the nascent carbonic oxide gas is passed over an ignited metallic oxide, it in either case effects a ready reduction of the metal.

Arsenic.—Mix half a grain of an arsenical compound with twice as much dry formate of soda. Insert the mixture (page 105) into a glass tube, one-tenth of an inch wide, and two inches long, and expose it to the heat of the spirit lamp as shown by the figure at page 35. In less than a minute, the experiment is ended, and metallic arsenic in the form of a sublimate appears at a little distance from the end of the tube. The hundredth of a grain of sulphuret of arsenic, or of an arsenite, or an arseniate can, according to Goebel, be thus reduced. When a metallic arsenite is thus decomposed, the base is also reduced, and upon washing the residue in an agate mortar to separate the soda, (see the reducing operation with soda) the metal is obtained in films. In case of admixture with sulphuret of antimony, a thousandth part of arsenic can be thus detected. Hence this method can be advantageously employed in the examination of the compounds of antimony that are used in medicine.

Copper.—By this operation, arsenite of copper is reduced to metallic copper and metallic arsenic.

Silver.—Arsenite of silver is reduced to metallic silver and metallic arsenic.

Mercury.—Calomel, corrosive sublimate, cinnabar, and nitrate of mercury, all undergo reduction. The smallest quantity produces a brilliant metallic sublimate. When this is slight, it can be gathered together by a wet platinum wire, and brought out of the tube into a watch glass.

Silver, the Nitrate and Chloride.—Both are easily and com-

26. Take two grains of sulphate of copper and two grains of charcoal in powder. Ignite them separately in a spoon with a cover or a small crucible or glass tube, to free them from water. Mix and heat them in a tube, as directed in the text, and observe the results of the decomposition.

27. Repeat the experiment with sulphate of lime or sulphate of barytes. You 'll find that neither of these sulphates is capable of decomposition by this process.

pletely reduced, and when washed in the mortar give brilliant spangles of metallic silver. The nitrate deflagrates during the reduction.

Salts of *Lead.*	All reduced.
Salts of *Antimony.*	
Oxide of *Zinc.*	Part of the cadmium remains at the heated spot, part of it gives a sublimate like that of arsenic, only brighter.
Sulphate of *Zinc.*	
Sulphate of *Cadmium.*	

The following reductions are effected by igniting the formate of soda so as to produce a current of carbonic oxide gas, and passing this over the metallic oxides.

Oxide of Copper.—A small quantity of dry formate of soda is to be put into a glass tube one-eighth of an inch wide, and six inches long. A little dry oxide of copper is to be placed about the middle of the tube, which must be held horizontally. The oxide of copper is to be heated to redness by means of a spirit lamp, and then the formate of soda is also to be heated. The latter is shortly decomposed, and a current of carbonic oxide gas is disengaged, which, in passing over the ignited oxide of copper, speedily reduces it to the metallic state.

Chloride of Silver, treated in the same manner, is rapidly converted into metallic silver, meanwhile a disengagement of phosgene gas takes place, which is readily known by its sharp action upon the eyes and nose, and by its splendid white flame.

Chloride of Lead also suffers decomposition under disengagement of phosgene gas.

SECOND OPERATION.

HEAT THE SUBSTANCE, ALONE, BEFORE THE BLOWPIPE, IN THE OPEN AIR.

OBJECTS IN VIEW.—To ascertain whether or not the substance

A, is Fusible,
B, Changes Colour,
C, Deflagrates,
D, Intumesces,
E, Colours the Blowpipe Flame,
F, Gives off Volatile Matter,
G, Behaves the same, or differently, in the Oxidating and the Reducing Flames.

METHOD.—According to the nature of the substance under operation, or to the particular object in view, you are to *support* the assay either on charcoal, in the platinum tongs, or on the platinum wire. I refer you to the description of these supports, given at pages 121—126.

A, TRIAL OF FUSIBILITY.

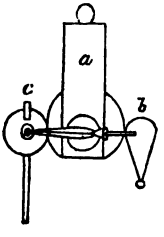
IF the substance is metallic, or a metallic oxide suspected to be easily reducible, or if it contains constituents of any kind

which it is expected may attack platinum at a red heat, it must be supported on a piece of charcoal. But if it be composed of substances that cannot attack platinum in the heat, it is best to use a thin splinter, and to hold it in the platinum tongs. The latter is by far the best method to adopt in the case of the silicates and various other minerals, which, consisting of the same constituents combined in different proportions, are often only readily distinguishable from one another by their different degrees of fusibility. The splinter for this purpose is struck from the mineral by the hammer, or is chosen from among the fragments produced by folding a piece of the mineral in paper, and crushing it on the anvil. The point of the splinter is held to the flame, and the effect is easy to be seen. Infusible minerals preserve the sharpness of their edges. Those which are difficultly fusible become rounded on the edges. Those easily fusible melt to a round bead. When you are uncertain whether or not the substance thus examined contains a reducible metal, you must take care to remove it from the fire before the fused portion of the assay comes near the platinum support. A splinter of sulphuret of antimony, held in the platinum tongs, may be fused upon the *point* without injury to the tongs; but if you allow the fusion to proceed till the melted antimony touches the tongs, the instrument becomes injured. To provide against this accident, whenever you perceive the assay to fuse readily, you should remove it from the tongs to a plate of charcoal (page 123), and renew the fusion thereon. If the substance for examination is in small grains, one of the grains must be laid in the cavity upon the charcoal. If it is in fine powder, a small quantity of it must be kneaded with water into a paste, and spread thinly in one of the little cavities upon the charcoal, where it can be dried before the blowpipe into a thin cake, and then be lifted by the platinum tongs to be farther heated. Whatever the support may be, the assay must be brought gradually into the blowpipe flame, and finally be held for some time in its hottest part. The oxidating flame is to be first employed, and afterwards the reducing flame.

Fusibility of the Metals.—Most of the metals *fuse* before the blowpipe, and, excepting the noble metals, become oxidised on exposure to the outer flame. Of the noble metals, *Gold* and *Silver* both melt, without suffering any further alteration. *Platinum*, *iridium*, *palladium*, *rhodium*, and *osmium* are all infusible; but the last by exposure to the outer flame, becomes oxidised, and volatilises in the state of osmic acid. All the salts of the noble metals, such as the nitrate of silver, and the chlorides of silver, gold, and platinum, suffer immediate reduction to the metallic state, when heated in the inner flame. Of the other metals whose oxides can, with the help of soda, be reduced to the metallic state, by a process to be hereafter described, the following are infusible—*molybdenum*, *tungsten*, *nickel*, *cobalt*, and

iron. Among the metals which have not been named, are several that are infusible, but they are all such as cannot be reduced to the metallic state by means of the blowpipe.[28. 29.]

Cupellation.—This operation is resorted to for the purpose of separating what are called noble metals from those which are more readily convertible into the condition of oxides. The operation consists in fusing the alloy on charcoal with pure lead, and then heating the resulting bead in the oxidating flame, upon a substance sufficiently porous to absorb the fused oxides produced by the ignition. The process terminates in presenting a bead of the noble metal free from admixture of oxidible metals. A condition of success is, that the alloy produced with the lead be fusible. If lead alone does not render it so, it is necessary to add silver, which must afterwards be separated by solution in an acid. I give the operation of cupellation a place here, because in the event of simple fusion before the blowpipe producing a bead of silver, gold, or other noble metal, it is proper to try whether the metal so produced is pure or contaminated with an oxidable metal. The method of proceeding is as follows. Take a small quantity of very finely pounded bone ashes. Mix it in the palm of your left hand, by means of a knife or spatula, with a little carbonate of soda, and a drop or two of water, into a stiff paste. Make a hole in a piece of charcoal similar to the cavity depicted at page 123, but with the larger end of the charcoal borer, page 123, and about a quarter of an inch deep. Fill this hole with the stiff paste made with the bone ashes, smoothing the surface by pressure with the round end of a pestle, and slowly dry the mass over the flame of a spirit lamp, or before the blowpipe. The soda serves to make the paste hold better together, but is not essential to the operation. The dried paste is called a *cupel.* Upon this cupel the alloyed metal is placed, and exposed for a considerable time to the heat of the oxidating flame. The lead, copper, tin, and other oxidible metals that may be present in the alloy, then become oxidised, and form fusible compounds which sink into the cupel, while gold, silver, and other noble metals remain in a brilliant globule upon the surface of the cupel. This method of assaying is so delicate that it almost always produces a bead of silver, when the common lead of commerce is submitted to trial. Of all the noble metals, only silver and gold can be obtained in fused beads by this pro-



28. Take a plate of charcoal, mounted as shown at page 123. Put a bit of nitrate of silver, the size of a pin's head, into the cavity, *a*, and expose it to the reducing flame of the blowpipe. In a short time the salt is decomposed, and brilliant metallic silver appears upon the charcoal.

29. Repeat the experiment with a little chloride of silver. A similar result is afforded.

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cess. The other metals produce only a grey infusible metallic powder.

FUSIBILITY OF THE METALLIC SULPHURETS.—Most of the metallic sulphurets fuse before the blowpipe on charcoal. This is even the case when they contain metals that produce infusible oxides. Many of them acquire oxygen during the fusion, disengage sulphurous acid, and produce metallic oxides.[30]

FUSIBILITY OF THE METALLIC OXIDES.—Most of the pure metallic oxides are infusible. Many of them are susceptible of being more highly oxidised by the outer flame, and of being partially and sometimes entirely reduced by the inner flame. I shall class the infusible and the fusible oxides separately.

Infusible Oxides. These are as follows:—

Barytes. Strontian.	Their Hydrates and Carbonates are fusible, but are speedily reduced by ignition on charcoal, and then act as infusible oxides. The Carbonate of Barytes is by far more fusible than that of Strontian.
Lime.	This gives a strong light.[31. 32.]
Magnesia.	
Alumina.	
Glucina.	
Yttria.	
Zirconia.	Gives an extremely powerful light.
Silica.	
Tungstic Acid.	
Oxide of Chromium.	

30. Heat a small bit of sulphuret of antimony, on charcoal, in the oxidating flame. Observe the fusion of the substance and the disengagement of the sulphurous acid. The latter is detected by holding the assay to the nose immediately upon removing it from the blowpipe flame.

31. Take one grain of lime, slake it with water, and knead it in the palm of the left hand by means of a knife or spatula into a paste. Place it in the cavity of a piece of charcoal. Dry and ignite it before the blowpipe. You will find it to be infusible, and that when strongly heated it shines with a very bright light.

32. Repeat this experiment with barytes, strontian, magnesia, alumina, and silica. You will find that none of these earths can be fused, but that they shine with different degrees of light when under strong ignition. The light that is given by alumina, for example, is wholly unlike that given by lime, both in brilliancy and tinge of colour. Hence, when alum is ignited, you can infer from the kind of light which it displays, that the earth present in the salt is not lime but alumina. In the examination of siliceous minerals, the earth which they contain in greatest quantity can sometimes be pretty accurately inferred from the kind of light displayed by the mineral when ignited alone.

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Infusible Oxides, continued.

Antimonious Acid.	Reduced in the inner flame to volatile oxide of Antimony, and to fusible metallic antimony.[33]
Tantalic Acid.	
Titanic Acid.	
Uranium, Protoxide.	
Uranium, Peroxide.	Reduced to Protoxide.
Cerium, Protoxide.	Changed to Peroxide.
Cerium, Peroxide.	
Manganese, Peroxide.	If strongly heated loses a part of its oxygen, and becomes brown.[34]
Zinc, Oxide.	Reduced by the inner flame and sublimed. It is yellow while hot, and white when cold. It shines with a bright greenish light while hot.[35]
Cadmium, Oxide.	Reduced by the inner flame and sublimed, if heated on charcoal. The deposit is red when cold. It is much easier volatilized than oxide of zinc.
Iron, Peroxide.	Deprived of part of its oxygen in the inner flame, and rendered black and magnetic.[36]
Nickel, Oxide.	
Cobalt, Oxide.	
Tin, Protoxide.	Takes fire and burns into Peroxide.
Tin, Peroxide.	Can be reduced in the inner flame, but not easily without fluxes.

Fusible Oxides.—They are very few in number.

Oxide of Antimony.	Sublimes after fusion.
Oxide of Bismuth.	Easily reduced to metal.

33. Heat a little antimonious acid on charcoal before the blowpipe. In the oxidating flame it is infusible. In the inner flame it is reduced, giving a sublimate of volatile white oxide of antimony and a bead of fusible metallic antimony.

34. Heat strongly on charcoal before the blowpipe, a small quantity of black oxide of manganese. You will find it to be converted into the brown oxide of manganese, in which there is less oxygen in proportion to the quantity of metal.

35. Heat a small quantity of oxide of zinc in a cavity on charcoal, first in the oxidating flame, and afterwards in the reducing flame. The oxide is white when cold, but turns yellow when heated, and shines with a peculiar green light. In the reducing flame, the oxide is reduced, and the metal is sublimed. When the reduced metal sublimes it takes fire and burns to oxide, long streaks of intense whitish green light appearing at the same instant.

36. Heat, strongly, a small quantity of red oxide of iron in the reducing flame. Observe the change of colour to black, and the assumption of magnetism.

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Fusible Oxides, continued.

Oxides of Lead.	Easily reduced to metal. Red lead turns black when heated, and produces yellow oxide. The yellow oxide fuses to a brown glass, and is then reduced.
Oxide of Copper.	Melts to a black bead, and is then reduced.
Vanadic Acid.	Fuses on platinum foil to a red liquid which crystallizes on cooling.
Molybdic Acid.	Smokes and fuses on platinum foil to a brown liquid, which becomes yellow and crystalline on cooling. In the reducing flame it turns blue. It is reducible on charcoal.
Tellurious Acid.	Fuses on platinum wire. Upon charcoal, it fuses and is reduced.[37]

Fusibility of the Silicates and other Minerals.—The trial of *fusibility* is very important in respect to silicates and other minerals, which, consisting mostly of earths, and containing no metals in remarkable quantity, have scarcely any other pyrognostic character than different degrees of fusibility to distinguish them from one another. As before remarked, the best way to test the fusibility of minerals is to heat a thin and pointed splinter held in the platinum tongs. See page 124. The splinter must be very small and thin, because the hottest part or focus of the flame is in itself small and therefore unfit to ignite a large object. A tabular view of the different degrees of fusibility of the most important minerals, will be given in the description of the "Fourth Operation," which will also contain an account of a method for the still closer discrimination of minerals, by an examination of the products afforded by their fusion with carbonate of soda.

Fusibility of Soluble Salts.—Most of the salts and saline compounds that dissolve in water, melt when ignited on charcoal before the blowpipe. They often, however, suffer a prompt decomposition, and produce an infusible base or oxide. When they contain water of crystallization, they first melt in the water, then become dry, and afterwards undergo the igneous fusion. The alcaline salts, after fusion, sometimes sink into the charcoal and disappear, and sometimes form glassy beads.[38] [39]

37. Examine the fusibility of any of these oxides in the oxidating flame, and attempt their reduction in the inner flame. Use a very small piece of each substance.

38. Heat upon charcoal a small quantity of carbonate of soda. It melts and sinks into the charcoal.

39. Heat in like manner a small quantity of microcosmic salt. It melts and forms a clear round glass bead.

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FUSIBILITY OF INSOLUBLE SALTS.—Some of the insoluble salts fuse to beads, which on cooling crystallize. This is strikingly the case with the Phosphate of Lead, of which this property is the characteristic phenomenon.[40]

B. CHANGES OF COLOUR PRODUCED BY IGNITION.

ALL organic bodies become black or charred. Other changes of colour experienced on exposure to heat, are frequently occasioned by the production of new compounds; but there are a few substances which have the property, independent of alteration in composition, of changing colour with change of temperature; and which, after exposure to heat, resume on cooling their original colour. For such substances this is a characterising phenomenon; it is of use, however, in only a few cases.

Oxide of Zinc. Titanic Acid. — These two compounds are white when cold, and lemon-yellow when hot. This is the case with several other white substances, but not in quite so remarkable a degree.

Minium. Peroxide of Mercury. Chromate of Lead. Chromates in general. — These are red or yellow when cold, and black when hot. The temperature must never be raised so high as to decompose them.[41]

Peroxide of Lead. Oxide of Bismuth. — The common colour of these substances becomes deeper on exposure to heat.

C. DEFLAGRATION.

SEVERAL species of salts on being heated on charcoal distinguish themselves by deflagration or explosion. These are the Nitrates, Chlorates, Iodates, Bromates, and Chromates. The deflagration of the last is feeble.[42]

D. INTUMESCENCE.

THIS character distinguishes the following minerals from all others. Their different degrees of fusibility discriminate them from one another.

40. Melt a small quantity of phosphate of lead on charcoal in the oxidating flame. When completely fused to a bead, allow it to cool. You will find it, when cold, to exhibit, not the round surface that it did when hot, but numerous flat faces, like the planes of imperfect crystals, such as those of Pyrope.

41. Heat gently on charcoal in the oxidating flame a small quantity either of minium or of chromate of lead. Observe the change of colour when hot, and the revival of the original colour when the substance becomes cold.

42. Heat a small quantity of nitrate of potash on charcoal before the blowpipe. The deflagration is similar to that produced by dropping charcoal powder into melted nitrate of potash (page 133).

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Fuse to Beads.		Become slaggy on the edges only.
The Zeolites, *namely*—	Onkosine	Epidote
1. Apophyllite	Boracite	Zoisite
2. Chabasite	Hydroboracite	Green Tourmaline
3. Mesotype	Datolite	Lazulite
4. Mesolite	Botryolite	Plombgomme
5. Mesole	Axinite	Mica, from Granite
6. Analcime	Hydrosilicate of Manganese	Hornblende
7. Thomsonite	Lithion-Spodumene	Euclase
8. Stilbite	Scapolite :	Sphene
9. Epistilbite	*a.* Meionite	Infusible.
10. Heulandite	*b.* Wernerite	
11. Brewsterite	*c.* Dipyre	
12. Laumonite	*d.* Ekebergite	Gadolinites (some)
13. Harmotome	Elæolite	Lithion-Tourmaline
14. Scolezite	Idocrase	Aeschynite
15. Prehnite	Cerine	Pyrophyllite
16. Edingtonite	Orthite	Alum
		Sulphate of Alumina

E. PRODUCTION OF COLOURED FLAMES.

Several substances communicate very striking *colours* to the blowpipe *flame*, either when exposed to it alone, or when mixed with particular re-agents. The character is very definite, and of considerable importance. The colours commonly produced are blue, green, yellow, and red. It is in general the outer portion of the blue oxidating flame to which colours are communicated. The experiments require to be made in a dark room, and with a very small flame. The substances by which colours are produced are as follows:—

Blue Flames.

Large intense blue	Chloride of copper
Pale clear blue	Lead
Light blue	Arsenic
Blue	Selenium
Greenish blue	Antimony
Blue mixed with green	Bromide of copper.

Green Flames.

Very dark green, feeble	Ammonia
Dark green	Boracic acid
Dark green	Iron wire
Full green	Tellurium
Full green	Copper

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Green Flames, continued.

Intense emerald green	Iodide of copper
Emerald green, mixed with blue	Bromide of copper
Pale green	Phosphoric acid
Very pale apple green	Barytes
Intense whitish green	Zinc

Yellow Flames.

Intense greenish yellow	Soda
Feeble brownish yellow	Water

Red Flames.

Intense crimson	Strontian
Reddish purple	Lithia
Reddish purple	Lime
Violet	Potash

Such are the colours and the substances which the colours indicate. It may not be improper to mention the circumstances that are found to be favourable to the production and observation of these colours.

WATER.—If a splinter of almost any mineral is held in the oxidating flame, close before the point of the inner blue cone, it exhibits a slight brownish yellow flame, extending as a tail a short way beyond it, but having little intensity, and soon disappearing. I attribute this to the presence of water.

SODA.—If a little sulphate of soda is melted on a platinum wire, and exposed to the same part of the blowpipe flame, it exhibits a long and brilliant stream of greenish yellow light, such as can be produced by no substance free from soda. Every salt of this alcali, metallic sodium, and every mineral of which it is a constituent, gives the same yellow flame. The manner of exposing a salt of soda to the flame of the blowpipe is shown in the following figure; where *b* is the blowpipe, *a* the

oxidating flame, *c* the platinum wire upon which the soda of salt is fused, and *d* the tail of yellow flame, by the production of which soda is distinguished.[43. 44. 45] The wire must be scrupulously

43. Examine any salt of soda in this manner, and you will produce the yellow flame. Observe with what a very small quantity of a soda salt the flame can be produced, and to what length, often more than two inches, the flame can be extended.

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cleaned, and must be wetted in distilled water to make the salt adhere—*never in the mouth*, because the saliva contains sufficient soda to colour the blowpipe flame.

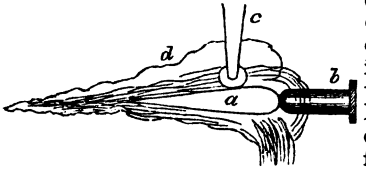
POTASH.—If a little saltpetre is treated in the same manner, it exhibits a reddish or violet-coloured flame, the form of which is short and spread, and not tail-shaped, like the soda flame. It is also of but little intensity; and though characteristic of all the compounds of potash, it is scarcely exhibited visibly by some of them.[46] The presence of a three hundredth part of soda in admixture with a potash salt is sufficient to overwhelm the potash flame, and make the colour of soda predominate. On this account, when the two alcalies occur in the same mineral, soda alone can be detected by this character.[47]

The only method of detecting by the blowpipe the presence of potash in a mixture of potash and soda, is to fuse a clear bead of borax on the platinum wire, (see Sixth operation,) then to melt into it a small quantity of oxalate of nickel, so as to give it a brown colour, and finally to fuse with it the substance that contains potash. This changes the brown colour of the nickel bead to blue—while no such change of colour occurs upon the addition of a salt of soda.

Salts of soda and potash are distinguished from those of earths and metals, by fusion with carbonate of soda upon platinum foil. If any solid infusible substance appears in the fused mass, it indicates the presence of some other substance than an alcali.

STRONTIAN. Hold in the platinum tongs, point downwards, a bit of chloride of strontium moistened with water, and let it dip into the blue cone of the oxidating flame, nearer to the wick than to the point of the flame. At the instant of touching, a brilliant crimson light shoots along the upper part of the flame.

The annexed figure exhibits the method of making this experiment. Letter *b* represents the nozzle of the blowpipe, *a* the blue cone of the oxidating flame, *c* the points of the platinum tongs holding the moistened assay, which is represented by the little circle just over *a*. The outline *d* represents the form of the flash of coloured



44. Make a comparative experiment with a small piece of gypsum, held in the platinum tongs, to learn the different colour and form of the yellow flame producible by moisture.

45. Examine a splinter of the mineral called Thomsonite, which exhibits the soda flame. So does Albite and all other minerals that contain soda.

46. Examine nitre in this manner, and observe the violet-coloured and short scattered flame of potash. The salts of potash that give the violet flame most distinctly cannot be made to give so long a tail of flame as that producible by salts of soda.

47. Mix one grain of sulphate of soda with 200 grains of sulphate of potash, and examine a portion of the mixture. The yellow flame will be found predominant.

flame which is produced the instant the assay comes into contact with the blue cone of the oxidating flame. The blue cone should be made as free as possible from white light. The platinum tongs must be carefully cleaned for this experiment.

Any salt of strontian that dissolves in water, acts in the same manner. The colour is not seen so well if the assay is not moistened, nor is it seen so well if an insoluble salt is made use of. If the assay, instead of being dipped into the upper part of the flame, is held at the point of it, in front, as directed in the trial of soda, the colour is not so well developed, and after the salt melts, the colour is seen no longer; these different methods of proceeding are necessary with different substances. Strontian, indeed, will colour the flame both ways, but other substances will not.

It may be stated as a general rule, applicable to salts of the earths, but not to salts of the alcalies, that soluble substances should be moistened with their proper solvents, and *dipped into* the flame; while insoluble substances should be held in a dry state, beyond the *point* of the flame.[48. 49]

If *carbonate* of strontian is to be tried, it must be moistened with muriatic acid instead of water. It then acts the same as chloride of strontium moistened with water. If sulphate of strontian is to be tried, it must be finely pulverised, mixed with charcoal powder and grease, spread thinly on the charcoal, and strongly heated in the reducing flame. By this process, which is sufficiently troublesome, it is reduced to sulphuret of strontium and rendered soluble in muriatic acid. If the reduced matter holds together in a cake it may be lifted in the platinum tongs, moistened with muriatic acid, and dipped in the upper part of the flame, upon which it will give the crimson light. The sulphate of strontian in its natural state, gives a slight crimson flame when held at the point of the blue cone, but it is not very distinct.[50]

Lithia.—What has been said of strontian applies to this alcali almost verbatim. The colour of its flame has, however, a slight tendency to purple, though the difference is not great. The flame, moreover, is distinctly produced before the point of the blue flame, and is particularly *durable*, especially when chloride of lithium is employed, while chloride of strontium submitted to the same experiment, colours the flame but for an instant, the colour disappearing as soon as the salt melts. The minerals that contain lithia seldom exhibit its crimson flame, in consequence of the presence of soda. A flux consisting of 1 part of

48. Examine in the manner here pointed out, the coloured flames produced by chloride of strontium moistened with water, by nitrate of strontian moistened with water, and by carbonate of strontian moistened with muriatic acid.

49. Examine the flames produced by the same salts held dry at the point of the oxidating flame.

50. Repeat the experiment on the reduction of sulphate of strontian to sulphuret of strontium.

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fluorspar, and 1½ parts of bisulphate of potash, finely powdered, mixed, and heated before the blowpipe with silicates containing lithia, sometimes occasions the production of the red flame.

LIME.—The remarks made on strontian apply almost equally to lime. The colour of the flame is not greatly different. When arragonite and pure calcareous spar are moistened with muriatic acid, and tried as before directed, they produce a crimson light, very difficult to be discriminated from that produced by strontian. It is, perhaps, more of a purple hue, but the difference is not such as to distinguish one earth from the other with sufficient precision.

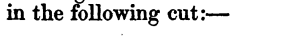
The remarks on the influence of solubility and insolubility, and on the management of the carbonate and sulphate of strontian, apply exactly to the salts of lime.[51, 52]

BARYTES.—The soluble salts of this earth dipped in water and then in the blue flame, in the same way as the salts of strontian and lime, produce a bright apple-green flame. Barytes exhibits little or no colour at the point of the blue flame. It shows scarcely any colour if not moistened, and its insoluble salts produce hardly a vestige of colour.

If the acetate of barytes, moistened with water, is dipped into the flame, it exhibits the green light; if it is suffered to burn to carbonate, it exhibits no light. If the carbonate is moistened with acetic or muriatic acid, it again exhibits the green light.

These experiments prove that solubility in water is an important requisite for the production of coloured flames by salts of the earths.[53]

CHLORIDES.—IODIDES.—BROMIDES.—I class these compounds together, because they are all discriminated by the same experiment. Take a very fine copper or brass wire as thin as fine sewing cotton. Bend the end of it into a ring about one tenth of an inch across, and twist the wire across the middle of the ring, so as to make a figure somewhat resembling the Greek letter φ, as shown in the following cut:—



51. Repeat these experiments, using chloride of calcium and nitrate of lime, moistened with water, and a morsel of calcareous spar moistened with muriatic acid.

52. Reduce a small piece of gypsum to sulphuret of calcium, moisten it with muriatic acid, and dip it in the oxidating flame.

In all these cases, you will observe a red flame, scarcely to be distinguished from that produced by strontium.

53. Repeat these experiments, employing chloride of barium, nitrate of barytes, carbonate of barytes, acetate of barytes, and sulphate of barytes, in five separate experiments. The salts of these earths are presented for examination so frequently, that it is necessary to be acquainted with their habitudes.

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Melt a little microcosmic salt in this ring, the complex form of which is intended to prevent the salt from dropping from it when melted. Apply a gentle heat, and desist when the melted bead has done effervescing and has acquired a pale green colour. Add to this bead any substance suspected to contain chlorine, iodine, or bromine, or any of their compounds. A portion, the sixth part of a pin's head in size, is sufficient. Then plunge the bead suddenly into the oxidating flame, exactly before the point of the blue cone.

If *chlorine* is present, there will be instantly produced a splendid bright blue flame.
If *iodine* is present, an intense emerald green flame.
If *bromine* is present, a bright blue flame with emerald green edges.[54]

The end of the brass wire is to be cut off and thrown away after every experiment, so as always to leave a new support for succeeding trials.

Boracic Acid.—The borates are mixed with two parts of a flux formed of 1 part of pulverised fluorspar and 4½ parts of bisulphate of potash. The mixture is applied by water to the end of a platinum wire, and held at the point of the blue flame. Soon after fusion takes place, a dark green-coloured flame is seen merely for an instant. This is Dr Turner's process. I find the green flame of boracic acid very easily producible by dipping the borates moistened with sulphuric acid into the upper part of the blue flame, as directed for strontian. The flame is much more distinct in that position than at the point of the flame. When the borates contain soda, which is very frequently the case, in consequence of their being prepared with boracic acid imperfectly separated from borax, then the dark green flame of the boracic acid is so much affected by the yellow flame of the soda that the colour which is produced, more resembles the pale green flame of barytes than it does the deep green flame of boracic acid.

If the borates are heated on charcoal with a drop of sulphuric acid, and then moistened with few drops of alcohol. The latter, though absorbed by the charcoal, burns with a green flame when presented before the blowpipe flame.

If minerals that contain boracic acid are fused on charcoal with carbonate of potash, and then treated with sulphuric acid and alcohol, the same green flame is produced. This process is effective with black tourmaline and other minerals containing but a small quantity of boracic acid.

54. Repeat this experiment with any of the compounds of Bromine, Iodine, and Chlorine that you may have at hand. It succeeds even with the volatile compounds. Try calomel, common salt, chlorate of potash, sal ammoniac, chloride of lead, iodide of lead, iodide of potassium, bromide of potassium.

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PHOSPHORIC ACID.—When the phosphates are moistened with sulphuric acid, held in the platinum tongs, and placed at the point of the blue flame, they give a green colour to the outer flame. The colour is much paler than that of the flame of boracic acid, it is not always produced by the phosphates, and it is farther distinguished by being producible only at the point of the flame and not when dipped into the upper part of it.

COPPER.—Nearly all the compounds and ores of copper produce a very beautiful green flame, when exposed to the blowpipe flame. The colour of the flame produced by this metal is completely changed, when chlorine, iodine, or bromine is present. The soluble compounds of copper give a much more beautiful flame than those that are insoluble, and they act best when moistened with water and dipped into the upper part of the flame.

The native carbonate and sulphuret of copper require to be moistened with an acid. The sulphuret should be previously roasted. If sulphuric acid is used, the flame produced is a rich green. If muriatic acid is used, the flame becomes of that brilliant blue which characterises the compounds of copper and chlorine.[55] [56] [57]

LEAD.—All the minerals that contain lead communicate a beautiful clear blue colour to the flame. There is no difficulty in producing it. A thin splinter may be held with safety in the tongs, but small pieces of ore must be tried on charcoal.

ANTIMONY.—This metal produces a greenish blue flame.

ARSENIC.—Metallic arsenic produces a very light blue flame.

ZINC.—Oxide of zinc shines when strongly heated with a bright green light, and occasionally gives a narrow stream of green light, especially when exposed to the reducing flame; but it gives no large flame, and its soluble salts produce no colour when moistened and dipped into the blue flame.

TELLURIUM.—The fine green flame of tellurium is produced by directing the reducing flame upon a portion of volatile oxide of tellurium placed upon charcoal.

IRON WIRE.—Very thin iron wire burns with a green light. The character is of no value as respects the detection of iron, but

55. Examine crystallized sulphate of copper, moistened with water, and dipped into the flame.

56. Examine native carbonate of copper, moistened with sulphuric acid.

57. Examine native sulphuret of copper, first roasted on charcoal in the oxidating flame, then held in the platinum tongs, moistened with muriatic acid and dipped in the blue flame.

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the fact that finely-divided iron does burn with a green flame, is necessary to be borne in mind, in the discrimination of unknown substances by this character.

AMMONIA.—The salts of ammonia, the instant before they disappear in vapour, on being heated before the blowpipe, produce a feeble dark green flame. It can only be seen when the room is quite dark, and is a character of no importance.

This concludes the subject of Coloured Flames. I recommend the student to repeat the experiments till he becomes fully master of them. They are easy of execution, and the results are very striking. Many other substances besides those I have named in the notes will occur to him as adapted for similar experiments. I have only cited a few by way of example.

Several of these coloured flames can be produced without using the blowpipe, by holding the substances, duly prepared, in the small blue flame afforded by a spirit lamp having the cotton pushed down almost entirely into the wickholder or by a gas light very nearly extinguished. But the range of power belonging to the blowpipe flame renders it generally preferable for these experiments.

F. VOLATILE SUBSTANCES.

As substances which volatilize from charcoal before the blowpipe cannot be caught and subjected to farther examination, they can be discriminated only partially, by the sublimate they produce on the coal, by their odour, by the colour they give to the flame, and by the nature of the fixed residue which they may leave.

VOLATILE SUBSTANCES.

Volatile Metals.—Those which produce a sublimate upon the charcoal are—

Zinc	Antimony	Lead	Cadmium
Tellurium	Arsenic	Bismuth	Tin (slight.)

Those which are volatile and give no sublimate, are—

Mercury Osmium.

Volatile Oxides.—All oxides formed by volatile metals are reduced and volatilized by the reducing flame.

Many *Chlorides*, *Bromides* and *Iodides* are volatile.

Selenium, *Sulphur*, and all *non-metallic Elements* and their *compounds with one another*, are volatile—some of them, as muriate of ammonia, give sublimates. Hence, all *organic substances* are volatile before the blowpipe flame.

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NON-VOLATILE SUBSTANCES.

All *Metals* and *Oxides* which deposit no sublimate when heated on charcoal. These are—

Cerium	Tin (partly)	Palladium	Tantalum
Manganese	Uranium	Rhodium	Tungsten
Iron	Copper	Platinum	Molybdenum
Cobalt	Silver	Iridium	Vanadium
Nickel	Gold	Titanium	Chromium.

The *Salts* of these Metals, except a few which partially volatilize undecomposed, such as the chlorides of iron, copper, tin, and chromium.

All *Alcalies*, *Earths*, and their *Salts*.

The ODOURS produced by volatile substances before the blowpipe, are these:—The odour of *garlic* which characterises the vapour of metallic arsenic; that of *decayed horse-radish* which indicates the presence of selenium; that of *burning brimstone*, which indicates the presence of sulphurets, and the various odours peculiar to the different acids, and to cyanogen, ammonia, and organic substances.

The odours of selenium and sulphur are best developed by the oxidating flame, that of arsenic by the reducing flame.

G. DISSIMILAR ACTION OF THE OXIDATING AND REDUCING FLAMES.

SUBSTANCES heated before the blowpipe on charcoal are often very differently affected by the *outer* and *inner* flames, or more properly speaking, by the oxidating and reducing flames.

ACTION OF THE OXIDATING FLAME.—The effects produced by the oxidating flame are frequently similar to those produced by igniting the substance in the open glass tube, of which I shall speak in the next section. Frequently, however, the oxidating flame is used to prepare substances for more effectual treatment by re-agents. Thus, sulphurets and arseniurets are roasted on charcoal, in the oxidating flame, with a view to drive away the sulphur and arsenic in the state of sulphurous and arsenious acids, and to obtain their metallic bases in the state of oxides.

Metals that become Oxidised when heated on charcoal in the Oxidating Flame.—Most metals become oxidised, except Mercury, (which volatilises), Silver, Palladium, Rhodium, Platinum, Iridium and Gold.

If a powder is deposited around the assay upon the charcoal it shows the metal to be of the volatile class. The thicker the smoke produced, and the more abundant the sublimate, the more

volatile may the metal be held to be. The nature of the metal is judged of from the colour of the sublimate, its quantity, and its distance from the cavity in the charcoal where the metal is heated.

White sublimates indicate	Zinc Tellurium Antimony		Arsenic. Tin (slight)
Yellow sublimates indicate	Lead	and	Bismuth.

Dark Yellow sublimate indicates Cadmium.

Pale Blue sublimate indicates Antimony, in small quantity, the charcoal shining through it.

The ash of the charcoal sometimes appears like a sublimate; but it is distinguished by remaining fixed on the same spot after ignition in the reducing flame, by which ignition the sublimates are reduced and volatilised.

Sulphur and *Sulphurets*, as I have said, become oxidised, and burn with a blue flame, and give off sulphurous acid gas. The method of properly effecting the roasting of sulphurets, I shall describe when treating of reduction by soda.

Selenium and *Seleniurets* exhale the odour of decayed horse radish.

Arseniurets, *Antimoniurets*, and *Tellurets*, produce a sublimate of arsenious acid, oxide of antimony, and oxide of tellurium. The presence of arsenic is very injurious to the action of the fluxes, and it requires to be carefully removed by roasting. The operation is, however, of difficult execution. The arseniurets require to be alternately heated, yet not strong enough to effect fusion, in the oxidating and reducing flames. If fusion takes place before the separation of arsenic is complete, the assay must be pulverised, mixed with nitre and deflagrated on the charcoal. By washing in the mortar, in the manner described in the article treating of reduction by means of soda, the base of the arseniuret may be sometimes then obtained in the state of metal or of oxide.

Carbonaceous Substances, (coal, anthracite, &c.) burn before the oxidating flame, with or without flame, according to the presence or absence of bitumen, &c.

Organic Substances, as already explained, burn with flame, and produce charcoal.

Action of the Reducing Flame.—It deprives metallic oxides and their salts of a portion or the whole of their oxygen; producing reguline metals, sulphurets, &c. The reductions are effected upon charcoal.

Reducible Substances.

Metals Reducible.—Those which are contained in all metallic oxides, excepting

The Alcalies	Manganese	Tungsten
The Earths	Iron	Vanadium
The oxides of Cerium	Titanium	Chromium
The oxides of Uranium	Tantalum	

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The reduced metals are of two kinds, *volatile* and *fixed*. If the metal under examination is of the volatile description, nothing remains in the cavity on the charcoal after the reduction. If it is a fixed metal, you will perceive one or more microscopic globules of metal. These are to be taken from the charcoal, and examined as to their brittleness or malleability, (page 5), and as to their solubility in muriatic or nitric acid.

Metallic Salts, the acids of which are volatile, or decomposable by heat, as are all those of organic origin, are without exception also reducible.

Sulphates of Alcalies and Alcaline Earths are reduced to sulphurets, which give sulphuretted hydrogen gas if moistened with muriatic acid.

Metallic Sulphurets, most of them suffer reduction.

Chlorides and Iodides, non-volatile and containing a common metal, suffer reduction, and give reguline metals.

Cyanides and Oxalates containing reducible metals, become charred and give metals.

NOT REDUCIBLE.

Metallic Salts, of acids that are not decomposable by heat, to wit, phosphates, borates, and silicates.

Chlorides, *Bromides*, *Iodides*, and *Fluorides*, of the metals of the alcalies and earths.

The *Sulphurets* of the same metals and also of the volatile metals—such as cinnabar, sulphuret of tellurium, sulphuret of antimony, and sulphuret of arsenic.

The reduction which substances experience in the reducing flame, is in almost all cases greatly facilitated by the addition of soda. I shall come upon this mode of treatment in describing the use of the fluxes.

USE OF NITRATE OF COBALT.—There are several substances not readily distinguishable by simple ignition, which acquire marked characters on being moistened with a strong solution of pure nitrate of cobalt, and then ignited on charcoal. These substances are alumina, magnesia, and oxide of zinc.

Alumina acquires a fine pale blue colour.

Magnesia acquires a pale flesh-red colour.

Oxide of Zinc acquires a bright green colour.

The substances to be tried, are to be *ignited* with the solution of cobalt, but not *fused*—the reason for which is, that minerals which contain lime or an alcali and no alumina, acquire a blueish colour from cobalt if fused, but not till then; whereas alumina produces a blue colour by ignition without fusion. The presence of metals in the assay, destroys the action of nitrate of cobalt, and the presence of potash in the re-agent is equally injurious, for it then produces a blue colour when it ought not, for example with silica and zirconia. A few other substances

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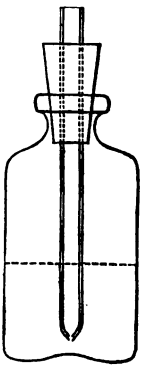
are slightly affected by nitrate of cobalt, and it is necessary to be aware of the fact, though the effects produced are not so striking as to be of use as discriminating characters. Barytes acquires a reddish-brown colour. Strontian, Lime, and several other earths, become dark grey or blackish. Barytes *fuses* with the nitrate of cobalt, but Strontian and Lime do not fuse. Silica becomes dark grey, but if very strongly heated, melts on thin edges to a reddish-blue glass. Titanic acid acquires a greyish black colour, and oxide of Tin becomes blueish green.

When a mineral that is to be examined for alumina or magnesia, is hard and solid, so as not to be able to suck a drop of the solution of cobalt into its pores, it is necessary before ignition to pulverise the substance in the agate mortar with water, till it forms a pap. A drop of this is then spread upon the charcoal, moistened with the solution of cobalt, and ignited. If the mass, when baked to a cake, loosens from the charcoal, it may be lifted by the platinum tongs to be further heated. When it has been heated bright red, it must be left till it is completely cold, and the colour be examined by day light.



The most convenient way of applying a drop of solution of cobalt, is by means of a small dropping tube, which may be passed through the cork of the bottle in which the solution is preserved.[58. 59. 60]

USE OF FLUORSPAR.—Pulverised fluorspar, free from water, fuses with either of the three anhydrous sulphates of lime, strontian, or barytes, into a colourless bead that becomes milk-white as it cools. It serves to distinguish these sulphates from other minerals, though not from one another. The fluorspar is to be used in rather smaller quantity than the sulphate. Previous to mixture, water is to be expelled from both substances by ignition. Only the oxidating flame is to be used in the fusion of the mixtures, as the reducing flame decomposes the fusible compound.

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58. Ignite a little bit of alum on charcoal to free it from water. Moisten it with a drop of solution of cobalt and ignite it again. Observe the blue colour of the product.

59. Repeat the experiment with a small quantity of sulphate of magnesia, and observe the flesh-red product that indicates magnesia.

60. Repeat the experiment with oxide or sulphate of zinc, to obtain the green substance.

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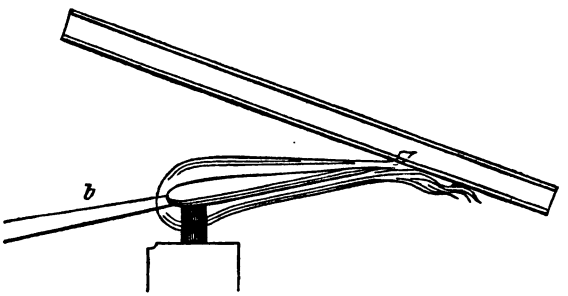
THIRD OPERATION.

HEAT THE SUBSTANCE IN A GLASS TUBE, OPEN TO THE AIR AT BOTH ENDS.

METHOD.—First apply the flame of the spirit lamp, and then urge the same flame with the blowpipe. For a more detailed account of the method of performing this operation, see page 121.



OBJECT OF THIS EXPERIMENT.—*To determine what description of volatile substances can be produced from the subject of experiment, by a current of atmospheric air acting at a high temperature.*

The volatile matters produced by this operation, if *gases* escape by the upper part of the tube, and are detected by their odour, or by their action upon test papers, and if *vapours* form sublimates on the inner part of the tube, more or less removed from the assay, according to their degree of volatility. We have therefore to consider—

A, The *odours* producible by this operation.

B, The *sublimates* producible by it.

A, ODOURS.

They are those of Sulphurous acid, Selenium, and Arsenic.

Odour of Sulphurous Acid.—When *metallic sulphurets* are heated in this manner, they disengage gaseous sulphurous acid, the slightest quantity of which is readily detected by the smell. The tube should be held in a position nearly horizontal, while the substance is undergoing ignition, and should be immediately afterwards brought to the nose, and at the same time be held almost upright, whereupon the gas readily escapes from the upper end. A bit of moistened Brazil wood test paper, inserted at this end of the tube, becomes bleached. Almost every metallic sulphuret disengages sulphurous acid in this process; a few, besides sulphurous acid, give a sublimate of sulphur, particularly those which give sublimed sulphur when heated in the

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closed tube. (See *First Operation.*) This effect, however, varies considerably, according to the angle at which the tube is held during the ignition. In a few cases, *sublimates* different from sulphur, are given by the metallic sulphurets, but these I shall come to speak of presently. The sulphuret of Zinc, and the native sulphuret of Molybdenum, give off sulphurous acid in this process, with more difficulty than any other of the sulphurets. The compounds of metals with sulphur and arsenic, which have been treated in the closed tube, and partly deprived of arsenic, still give sulphurous acid on being roasted in the open tube, for example, Arsenical Iron acts thus.[61. 62]

Odour of Selenium.—The metallic seleniurets, when roasted in the open tube, produce the odour of selenium. There is often produced, also, a red *sublimate* of selenium.

Odour of Arsenic.—A few arseniurets produce the odour of arsenic. This, however, is only when they are such as produce a sublimate of metallic arsenic, as well as of arsenious acid; when the latter alone is sublimed, there is no smell of garlic.

B, SUBLIMATES.

I COME next to consider the *sublimates* produced by roasting in the open tube. They are of two kinds, white and coloured.

A, WHITE SUBLIMATES.—These are produced by

1. Arsenious Acid	5. Oxide of Bismuth	9. Sulphuret of Tin
2. Oxide of Antimony	6. Oxide of Lead	10. Molybdic Acid
3. Oxide of Tellurium	7. Sulphuret of Lead	11. Mercury.
4. Chloride of Lead	8. Seleniuret of Lead	

1. *Arsenious Acid.*—It is produced by the roasting of arsenical alloys or arseniurets. It forms a white sublimate, which under the magnifier appears crystalline. Arsenious acid is sublimed by different arseniurets with very different degrees of facility. Glance Cobalt, and some other ores, for example, require a long ignition with the blowpipe flame. Some of them, as observed before, disengage both arsenious acid and metallic arsenic, while sulphuret of arsenic, and substances containing that compound, besides the sublimate of arsenious acid, commonly give red and even yellow sulphuret of arsenic, and that too when the tube is held almost horizontally. Arsenious acid is also expelled by this operation from substances which contain it in quantity ready formed, and from substances which contain arsenic acid.

2. *Oxide of Antimony.*—It is sublimed during the roasting of antimony, of metallic antimoniurets, sulphuret of antimony,

61. Heat a small piece of galena in an open tube, observing the instructions given above, and at page 121.

62. Repeat the experiment with mispickel, or any other native metallic sulphuret. Use test paper, and observe the effects produced by holding the tube inclined at different angles.

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and compounds containing sulphuret of antimony, and also when oxide of antimony, or its compounds, are thus treated. The sublimate is white, and has the property of being easily driven from place to place in the tube, by the application of a very slight degree of heat. In many cases, however, the sublimate produced by the roasting of antimonious substances in the tube, does not consist of oxide of antimony alone, but contains also antimonious acid. The latter is not a volatile substance, but being formed during the volatilization of the oxide in the current of air, it is carried with that sublimate, away from the substance assayed. Such a sublimate, consisting of oxide of antimony, and antimonious acid, is capable of only partial volatilization by heat. It is generally formed during the roasting of sulphuret of antimony, of compounds containing sulphuret of antimony, and of certain antimoniurets, the metals of which are readily oxidable. When the compounds of sulphuret of antimony contain lead, as, for example, is the case with the mineral Bournonite, then the roasting gives a white sublimate which is partly volatile and partly fixed, and consists of oxide of antimony and antimonite of lead.[63]

3. *Oxide of Tellurium.*—This sublimate is formed during the roasting of tellurium and the tellurets; and by the heating of oxide of tellurium and some of its compounds. The volatile oxide of tellurium forms a white smoke, which is far less volatile than the oxide of antimony; and instead of being driven from place to place by heat, like the latter, it has the property of melting into small colourless drops. When the tellurets contain lead, two sublimates are produced by the roasting. The one at greatest distance from the assay, is oxide of tellurium. The other consists of oxides of tellurium and lead, and is distinguished by not being fusible into drops.

4. *Chloride of Lead.*—This compound, when heated in the open tube, sublimes like oxide of tellurium; and the sublimate has also the property of melting into drops when heated. It is easy to discriminate the chloride of lead from the oxide of tellurium, by other experiments.[64]

5. *Oxide of Bismuth.*—It is formed in the tube by the oxidation of sulphuret of bismuth and alloys of bismuth, but seldom by the oxidation of metallic bismuth. The sublimate melts into drops when heated, but the drops are not colourless like

63. Roast a small piece of metallic antimony in an open tube, observing the precautions that have been pointed out, pages 121 and 160. Observe the sublimation of white oxide of antimony. Incline the tube at various angles while you apply heat to see the different effects of a slow and rapid current of air. Observe the facility with which the sublimed oxide can be driven from place to place in the tube.

64. Sublime a small quantity of chloride of lead in an open tube, and apply heat to the sublimate after deposition on the sides of the tube. Observe that, instead of flying unaltered from place to place, like the sublimate of oxide of antimony, it melts into round drops of a pale yellow colour.

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those of oxide of tellurium, but brownish or yellowish. The substance operated upon, when bismuth is present, becomes covered during the ignition with melted oxide of bismuth of a dark yellow colour, which gets paler as it cools. By this character, bismuth is easily distinguished from various other metals. It is, however, a character insufficient to distinguish it from *lead*, whose compounds under similar treatment present a similar accumulation of yellow melted oxide, the colour of which becomes paler as it cools.

Besides the white sublimates already described, there are a few produced by *particular compounds* of certain other metals.

6. *Lead, in a variety of Compounds*, if heated with substances that oxidate into volatile oxide and acids, generally rises in company with these substances.

7, 8. *The Seleniuret of Lead* and the *Sulphuret of Lead* give white sublimates of selenite and sulphate of lead, which become grey and melt if heated.

9. *Sulphuret of Tin.*—It gives a thick white smoke of oxide of tin, which does not again volatilize when heated.

10 *Molybdic Acid.*—It melts in the open tube and sublimes, partly as a white pulverulent sublimate, partly as shining pale yellow crystals. When sulphuret of molybdenum is roasted in this manner, it gives sulphurous acid gas only, and no sublimate.

11. *Mercurial Compounds.*—Most mercurial compounds give a sublimate of metallic mercury. Sulphuret of mercury sublimes in part undecomposed, and partly gives metallic mercury, and the latter being more volatile than the former, is deposited at a greater distance from the heated part of the tube. The two chlorides of mercury sublime in the open tube without suffering decomposition.

B. Coloured Sublimates are *not producible* by the operation of roasting in the open tube, but various coloured substances susceptible of sublimation in the closed tube, sublime also, and with still greater facility, in the open tube. See the "First operation."

FLUORINE.

I shall conclude the description of operations performed with the open tube, by detailing the method of detecting Fluorine.

In blowpipe experiments, the presence of fluorine is most difficult of detection in compounds of which it forms an essential constituent; as, for example, in fluorspar and topas, whereas in compounds where it appears to be present almost accidentally, and is in very small quantity, as in some varieties of mica, it is more easy of detection, especially if it happens to be associated with a little water. I have already spoken of the detec-

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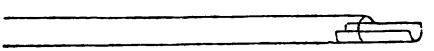
tion of fluorine in the latter case, (page 134.) To detect it in minerals of the first sort a different process is necessary. The fluoride in powder is added to a fused bead of microcosmic salt; the mixture is inserted into the end of an open glass tube, and the blowpipe flame is directed *into* the tube, so as to strike the mixture. By this means hydrofluoric acid is produced, which passes up the tube and corrodes its interior surface. This acid is also known by its peculiar odour, and by the yellow colour which it communicates to a moistened piece of Brazil wood paper inserted into the upper end of the tube. It is often useful to place the fluorine and the bead of fused microcosmic salt upon a bit of platinum foil, bent into a half cylinder and inserted into the lower end of the glass tube, so that the flame can be directed upon the mass within the platinum. This arrangement is represented in the following cut:—[65]



FOURTH OPERATION.

HEAT THE SUBSTANCE WITH CARBONATE OF SODA.

METHOD.—A small quantity of carbonate of soda is taken on the point of a knife or platinum spatula, and kneaded in the palm of the left hand, with a drop of water, till it forms a stiff paste. If the substance to be examined is in the state of powder, it is to be worked into the paste. If it is in a spangle or lump, the paste is to be spread upon it, and the mixture is to be placed in the cavity of a prepared plate of charcoal (page 123), and then to be exposed to the oxidating blowpipe flame. There should not be more of the paste than will fill half the cavity pictured at page 123. A gentle heat is to be applied at first, in order to dry the mixture. Afterwards, the heat is to be gradually increased to its highest point. The assay is then to be removed from the flame, and to be examined, first when it is hot, and again when it is cold. It is afterwards to be ignited in the reducing frame, and again to be examined, both hot and cold.

PECULIARITIES RESPECTING FUSION WITH SODA.—The soda commonly melts and sinks into the charcoal, but, as the heat continues it rises and attacks, if it is able to do so, the solid substance exposed to the flame in company with it. You observe a continual effervescence upon the assay; and, finally, that the edges of it melt away, and the mass fuses to a bead. When the soda is able to decompose a substance, but not to form a fusible compound with it, you observe a gradual swelling and change of appearance in the solid as the operation proceeds, but no formation of a bead. If too little soda is added, you sometimes ob-

65. Repeat this experiment with fluorspar.

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serve a clear bead surrounding an undissolved substance. If too much soda is added, the fused bead becomes opaque as it cools. In the former case, you must add more soda, in the latter, more of the unknown substance, and fuse the mixture anew with a view to produce, if possible, a glass wholly clear. There are some substances which give a bead with a small proportion of soda, but only a slag when a larger portion is added, on which account it is advisable always to begin with but a small quantity of soda, and gradually to add fresh doses, and to observe the effect of each.

Fusion on the Platinum Wire.—If the fusion of a substance with soda on charcoal produces no metal, the experiment may be repeated with the platinum wire instead of the charcoal support.

Object of this Operation.—To determine whether the substance is one that produces a Glass, a Slag, or a Reduced metal.

A. Only two substances, melted with soda upon charcoal, produce clear glass beads. The character is for these two substances very distinctive.

B. Many substances, chiefly mineral, produce beads more or less fusible and transparent when thus treated.

C. A variety of substances fuse with soda upon a platinum wire held in the oxidating flame. The substances which so distinguish themselves are in general the metallic acids. The experiment is not, however, one of great importance.

D. A great number of metallic oxides, when fused with soda on charcoal in the reducing flame, yield beads of metal, or, after suffering reduction, exhale volatile oxides, and deposit a sublimate upon the charcoal.

E. And finally, many substances are not attacked by soda at all, and neither undergo fusion nor reduction. The earths and some of the metallic oxides are thus characterized.

A. SUBSTANCES WHICH FUSE WITH SODA ON CHARCOAL, AND FORM A CLEAR BEAD.

There are only two—Silica and Titanic acid.

Silica.—When silica and soda are heated together on charcoal, they fuse, there is a disengagement of carbonic acid with effervescence, and the silica and soda produce a transparent colourless bead. No other substance acts with soda in the same manner. Some of the silicates also fuse with soda, but very seldom produce a clear bead. When a siliceous compound is heated with soda, it melts most readily when it contains much silica and little base, and has but a small quantity of soda added to it.

Sometimes the glass formed by soda and silica, acquires as it cools, a deep yellow or hyacinth red colour. When this happens,

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either the silica or the soda contains sulphur or a sulphate. If the colouring occurs with all the glasses produced by the same soda with other samples of pure silica, it proves the flux to contain sulphate of soda, in which case it is unfit for use with the blowpipe. But if the colouring only occurs in particular cases, it is to be inferred that the sulphur is present in the assay.[66·67·68]

TITANIC ACID.—Soda and titanic acid fuse on charcoal to a yellow glass, which on cooling becomes greyish white and opaque. It is never quite clear, like the glass formed by silica.

B. MINERALS WHICH PRODUCE BEADS OR SLAGS WHEN HEATED ON CHARCOAL WITH SODA.

I shall divide these Minerals into the following classes:—

I. Minerals that are Infusible
II. Minerals that Fuse to Beads } when heated alone.
III. Minerals that Fuse on the edges

Only *Oxidised* substances are embraced in these Tables.—No Sulphurets, Arseniurets, &c.

TABLE I.—INFUSIBLE MINERALS.

Produce Beads with Soda.	Produce Beads with a little Soda. Produce Slags with more Soda.	Produce Slags with Soda.
Quartz*	Phenakite	Thorite
Agalmatolite	Picrosmine	Andalusite
Hisingerite	Olivine	Staurolite
Sideroschisolite	Cerite	Gehlenite
Dioptase	Cyanite*	Chloritespar
Fire-clay*	Talc	Chrome Ochre
Leucite*	Gadolinite	Uwarowite
Pyrophyllite	Lithion-Tourmaline	Chromate of Iron
Wolkenskoite		Carbonates of the Earths*
Rutile		Carbonates of Metallic Oxides*
		Basic Phosphate of Yttria
Produce Slags with Soda.		——— of Alumina
		——— of Lime*
Allophane*	Peroxide of Tin (is reduced)*	Persulphate of Iron
Cymophane	Hydrate of Alumina	Sulphate of Alumina
Polymignite	Hydrate of Magnesia	Aluminite
Aeschynite	Spinel	Alum-stone*
Oerstedine	Gahnite	Fluoride of Cerium
Titaniferous Iron	Worthite	Yttrocerite
Yttro-Tantalite	Carbonate of Zinc	Topas*
Tantalite	Pechuran	Corundum
Oxides of Iron*	Zircon	Pleonaste
Oxides of Manganese*		Chondrodite

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TABLE II.

MINERALS THAT FUSE TO BEADS, ALONE.

Produce Beads with Soda.	Produce Beads with a little Soda. Produce Slags with more Soda.	Produce Slags with Soda.
The Zeolites* (See page 148.)	Okenite	Brevicite
Spodumene	Pectolite	Amphodelite
Soda-Spodumene	Red Silicate of Manganese	Chlorite
Labrador	Black Hydrosilicate of Manganese	Fahlunite
Scapolite	Idocrase	Pyrope
Sodalite (Greenland)	Manganeseous Garnets	Soapstone (Cornish)
Elaeolite	Orthite	Red Dichroite
Mica from Primitive Limestone	Pyrorthite	Pyrargyllite
Black Talc	Amblygonite	Black (Potash) Tourmaline*
Achmite	Sordawalite	Wolfram
Krokydolite	Sodalite	Pharmacolite
Lievrite	Fluorspar*	Scorodite
Cronstedtite		Arseniate of Iron
Garnet		Tetraphyline
Cerine		Heteposite
Helvine	Reduced Metal produced with Soda.	Uranite
Gadolinite (Kararfvet)		Phosphate of Iron
Boracic Acid		Sulphate of Strontian*
Tincal	Tungstate of Lead	Sulphate of Magnesia
Boracite	Molybdate of Lead	Polyhallite
Hydroboracite	Vanadiate of Lead	Hauyne
Datolite	Chromate of Lead	
Botryolite	Vauquelinite	
Axinite	Cobalt Bloom	
Lapis Lazuli	Nickel Ochre	
Eudialyte	Phosphate of Copper	
Pyrosmalite	Sulphate of Lead	
Cryolite	Chloride of Lead	
	Chloride of Silver	

*The Minerals that are distinguished in these three Tables by the sign *, are contained in* "GRIFFIN'S CABINET OF MINERALS FOR EXAMINATION BY EXPERIMENT."

Notes referred to in page 156.

66. Take a little silica in fine powder, half as much as the size of a pin's head; mix it with carbonate of soda, and fuse it as directed above, so as to produce a colourless transparent globule.

67. Repeat the experiment with silica and soda in different proportions.

68. Fuse one of the colourless beads thus produced with a fourth part of its bulk of any sulphate (sulphate of soda or gypsum). Observe the yellow colour due to the presence of sulphur.

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TABLE III.

MINERALS THAT FUSE ON THE EDGES, ALONE.

Produce Beads with Soda.	Produce Beads with a little Soda. Produce Slags with more Soda,	Produce Slags with Soda.
Steatite Meerschaum Felspar* Albite* Petalite Nepheline Anorthite Emerald Euclase Turquois Sodalite (Vesuvian)	Tabular Spar* Diallage Hypersthene Epidote Zoisite	Stilpnosiderite Plombgomme Serpentine Silicate of Manganese from Piedmont Mica, from Granite* Pimelite Pinite Blue Dichroite Sphene Karpholite Pyrochlore Tungstate of Lime Green (Soda) Tourmaline Lazulite Heavy Spar* Gypsum*

C. SUBSTANCES WHICH FUSE WITH SODA ON THE PLATINUM WIRE IN THE OXIDATING FLAME.

Silica.	Produces a clear glass.
Molybdic Acid.	Clear glass when hot. Milky when cold.
Tungstic Acid.	Clear dark yellow glass when hot. Crystalline, opaque, and yellowish when cold.
Chromium, Oxide.	Deep yellow glass while hot. Opaque and yellow when cold. In the reducing flame, opaque and green when cold. On charcoal, it fuses and is absorbed, but is not reduced.
Antimony, Oxides and Acids.	Clear colourless bead when hot. White when cold.
Tellurium, Oxide and Acid.	Clear colourless bead when hot. White when cold.
Titanic Acid.	Clear deep yellow glass when hot. Crystalline and grey-white when cold. Not reducible upon charcoal.
Vanadic Acid.	On charcoal, absorbed, but not reduced.

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Manganese, Oxides.	The oxides of manganese dissolve in but very small quantity; yet in so doing they communicate so fine a green colour to the soda, that this becomes one of the most delicate experiments for the detection of manganese. The colour is however better developed upon *platinum foil* than upon the wire.[69]
Cobalt, Oxide.	Fuses in small quantity to a pale red bead. On cooling, it becomes grey.
Lead, Oxide.	Clear colourless glass when hot. Opaque and yellowish when cold.
Copper, Oxide.	Clear green glass when hot. Opaque and colourless when cold.

D. REDUCTION OF METALLIC OXIDES, BY IGNITION ON CHARCOAL, WITH SODA, BEFORE THE BLOWPIPE.—

The reducing operation is performed as follows: The powder for examination is mixed in the palm of the left hand with wet soda to a paste. This is put into the cavity of a prepared plate of charcoal, which should be very solid for this experiment, and not less than half an inch thick. It is then heated in a strong reducing flame. A little more soda is afterwards added, and the ignition is renewed. And again, so long as any portion of the powder remains on the surface of the charcoal, fresh soda is added in small portions, and the blast is renewed. The heat must be strong, and the flame must cover the whole of the assay. By this means the mass is made to sink into the charcoal. A pretty strong flame is afterwards forced upon the spot for a short time. A few drops of water are added to extinguish the fire, and then all the burnt parts of the charcoal with the salts that have been absorbed, are cut out with a knife and put into a small agate mortar, care being taken to lose nothing in the transfer. The mass is ground to fine powder, mixed with water, and subjected to repeated gentle decantations, till the whole of the pulverised charcoal is removed from the mortar, care being taken all the while that no *metallic* particles flow over with the charcoal. No other precaution is necessary to prevent this, than that of allowing the contents of the mortar a little repose after stirring the water and charcoal together, before pouring off the matters that float. It is proper to use the washing bottle (page 80), in this process. When the charcoal is entirely removed from the mortar, the metal, if any was in the assay, will be found at the bottom of the mortar. If it is

69. Mix a grain of soda with the tenth of a grain of black oxide of manganese. Ignite the mixture upon a slip of platinum foil (page 96). Observe the green colour which is characteristic of manganese.

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an infusible or a brittle metal, it appears in the form of a metallic powder. If it is a malleable metal, it produces flat shining plates (see page 5). And in almost all cases the surface of the mortar exhibits numerous metallic streaks produced by the friction of the metallic particles during the pulverisation of the charcoal. Among the metals most easily reducible by this process, are tin and copper.

Should you not happen to possess an agate mortar adapted to the performance of the washing part of the operation, the best thing to use instead of the mortar is a small porcelain capsule. You place this in the middle of a flat dish or soup-plate, grind the charcoal in it by means of a porcelain pestle, and without lifting the capsule from the dish, wash out of it the lighter portions of the pounded charcoal by a jet of water from the washing bottle, applied in sufficient quantity to make the contents of the capsule overflow its edge. When the charcoal is all pulverised and removed by this method, the particles of metal can be seen at the bottom of the capsule.

Differences in the Substances which suffer Reduction when Heated with Soda, on Charcoal, in the Reducing Flame.

Some of the metals reduced by this process become volatilised by the heat of the reducing flame, and undergoing a contemporaneous oxidation, deposit upon the charcoal, at a certain distance from the assay, a sublimate of regenerated oxide. In this case, no metallic particles are procured by washing the fused mass in the mortar.

Other oxides reduced by this process, affording *fixed* metals, present their results when the charcoal is separated by the process of washing already detailed.

Nearly all the *compounds* of reducible oxides also, are reduced when treated by this process. Not only the salts which contain oxygen acids, but even the compounds formed by the metals of the reducible oxides with sulphur, selenium, chlorine, bromine, and iodine, although none of these compounds become reduced when ignited in the reducing flame without soda. It is necessary, however, when *sulphurets* are to be submitted to the reducing process, to roast them thoroughly in the oxidating flame before mixing them with the soda. The same precaution must be taken with the compounds of arsenic and selenium; for the presence of either of these three elements is very injurious in the process of reduction.

Method of Roasting Sulphurets.—As the metallic sulphurets fall very frequently to be examined by the blowpipe, and as the expulsion of the sulphur from them, and their conversion into metallic oxides, is at the same time a very necessary and very delicate operation, I shall describe it in detail.

If it is a factitious sulphuret which is to be decomposed, you

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make it into a thin cake by kneading with water. If it is a native sulphuret, you choose a very thin slice or splinter. You support it on charcoal, and expose it to the oxidating flame. At first, you apply a very gentle degree of heat, and take particular care to avoid fusion. If the sulphuret fuses accidentally you must begin with a fresh piece, or else reduce the melted portion to powder, and again heat it. When the roasting has proceeded to a certain extent, the sulphuret, or rather the oxide into which it is changed, is no longer in danger of fusing. You may then increase the heat, and endeavour to reduce the portion of sulphate which is generally formed during the roasting.

The slow and gradual application of the heat, is of great importance. By applying a strong heat, you fuse the sulphuret, and cannot drive off the sulphur. And if you merely roast the sulphuret into sulphate, instead of into oxide, the consequence is, that when you proceed to the reducing process with soda, instead of obtaining reduced metal, you only obtain sulphuret, and this, combining with the sulphuret of sodium, produces a soluble compound, which dissolves in the wash water and disappears altogether.

Volatile sulphurets can only be roasted in the open tube. The sublimed oxide can be afterwards gathered and examined.

It sometimes happens that the oxides to be reduced, are accompanied by irreducible matters that interfere with the operation. In this case, it is of considerable advantage to mix a little borax with the soda; the borax melts into a glass with the irreducible matters, and leaves the reducible oxides to the free action of the soda. The addition of borax is often of great use in reducing some of the compounds of tin.

REDUCIBLE METALS.—*Class* 1.—*Metals whose compounds suffer reduction when ignited with soda on charcoal in the reducing flame; and which produce volatile oxides, and deposit a sublimate on the charcoal.* These metals are,

1. Antimony	5. Zinc
2. Arsenic	6. Cadmium
3. Tellurium	7. Bismuth
4. Selenium	8. Lead

1. ANTIMONY.—Particles of reduced brittle metal are easily obtained, which, on being strongly heated, give off a thick smoke, and produce a white sublimate which falls upon the charcoal. This can be driven from place to place, either by the reducing or oxidating flame; but if the reducing flame is used, the bluish green flame of antimony is produced.

2. ARSENIC.—It gives a thick smoke and white sublimate of arsenious acid, deposited upon the charcoal at a good distance from the assay. The sublimate is easily volatilised, and if the reducing flame is employed, the odour of garlic is produced.

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3. Tellurium.—It gives a white sublimate, with reddish edges. It is easily removable by the oxidating flame, or driven off by the reducing flame, the latter producing a green flame; or if selenium be present, a blueish-green flame.

4. Selenium.—It affords a steel-grey shining sublimate, sometimes a little blueish. The sublimate is readily volatilised, and in the reducing flame produces a blue flame.

5. Zinc.—It produces no visible metallic zinc. It gives a sublimate which is yellow and reflects much light while hot, but is perfectly white when cold. The sublimate is not volatilised by the oxidating flame, but can be driven off by the reducing flame. If a drop of cobalt solution is put on the white sublimate and heated, it changes its colour to bright green. Minerals which contain zinc, upon being heated with soda on charcoal, deposit a sublimate of oxide of zinc.

6. Cadmium.—It gives no visible metal, but produces a reddish-brown sublimate, the colour of which is best seen when it is cold. The sublimate can be volatilised by either the oxidating or reducing flame.

7. Bismuth.—The compounds of this metal readily give particles of brittle metal, which crush under the hammer. After long exposure to the flame, it deposits a sublimate which is dark-orange when hot, lemon-yellow when cold, and in thin coats blueish. It can be driven from place to place either by the oxidating or the reducing flame, but gradually diminishes in quantity. It gives no colour to the blowpipe flame when volatilised, by which it is distinguished from antimony and tellurium.

8. Lead.—Its compounds very readily yield particles of metal, which flatten under the hammer, and do not crush like the particles of reduced bismuth. It deposits a sublimate which greatly resembles that of bismuth, both in its colour and the distance at which it rests from the assay.

Reducible Metals, *Class II.—Metals whose compounds suffer reduction when ignited with soda on charcoal in the reducing flame, and which give metallic grains and no sublimate.*

These metals are as follows:—

1. Molybdenum	6. Tin
2. Tungsten	7. Copper
3. Iron	8. Silver
4. Cobalt	9. Gold
5. Nickel	10. Platinum

The reduced particles of iron, cobalt, and nickel, are *magnetic*. The other metals are distinguished by their colours, malleability, &c.

Vanadium. This fuses and sinks into the charcoal, but gives no metal.

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When the compound submitted to reduction contains several metals, the result is often an alloy; but in other cases the reduced metals are obtained separately, as when iron and copper are present together.[70. 71. 72]

Several substances of frequent occurrence are detected by processes closely related to the one under consideration, for which reason I shall introduce them here.

ARSENIC.—Substances suspected to contain this metal in any state of combination must be mixed with soda, and heated on charcoal in the reducing flame. Whereupon the smallest portion of arsenic produces the peculiar *odour of garlic*, by which the vapour of this metal is characterised. The odour is not produced if the oxidating flame is employed, nor if the soda be omitted.[73]

SULPHUR.—The presence of sulphur in the *sulphurets* and *sulphates* is determined as follows:—The compound is ignited with soda, or with a mixture of 2 parts of soda and 1 part of borax, on charcoal, in the reducing flame, and the ignited mass is placed with a drop of water on a piece of bright silver, to which it communicates a yellowish-black stain. The use of the

70. These reducing experiments are of very great importance, as they give results of the most decisive kind, and act upon extremely small quantities of the metallic compounds. They cannot all be made properly without the help of a small agate mortar, though a good many operations can be performed with a small porcelain mortar, or even a porcelain cup with a smooth ground glass stopper as a substitute for a pestle. But if you possess an agate mortar, you should repeat as many of the processes as suffice to make you acquainted with the mode of operating. You may begin by operating upon half a grain of oxide of copper. Then upon a quarter of a grain. Then upon the eighth of a grain. Afterwards you may operate upon oxide of tin, assisting the reduction in the first experiments, by the addition of a little borax, then accomplishing it with soda alone, and working in successive experiments upon smaller and smaller quantities. To this metal may succeed nickel, and to that several of those that give sublimates; in working upon which, you are to observe particularly the distinctive characters of the different sublimates; as, for example, their different degrees of volatility; their different reactions in the oxidating and reducing flame; their difference in the distances at which they rest around the heated spot; their different colours, hot or cold; the different colours they give to the reducing flame; the brittleness or malleability of the metals they afford; and so forth.

71. You may then proceed to the roasting and reduction of some of the metallic sulphurets, such as the precipitated sulphurets of tin, lead, bismuth, copper, and silver.

72. And finally, you may examine some of the mineral sulphurets, such as Iron Pyrites, Sulphuret of Antimony, Galena, and Zinc Blende. The whole of these substances are contained in "Griffin's Collection of Minerals for Examination by Experiment." The price of this little cabinet, which comprehends 54 specimens of important minerals, adapted for experiments of this kind, is 10s. 6d.

73. Repeat this experiment with a portion of an arsenical compound not exceeding the tenth of a grain. You should produce a good result with even a smaller quantity than this.

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borax is to prevent the sulphuret of sodium from sinking into the charcoal as it is produced.[74]

Or, the compound is mixed with soda and silica, and fused on charcoal in the reducing flame till it forms a bead, which, if sulphur is present, has a dark-brown colour. These two experiments distinguish sulphur from all substances except selenium.

SELENIUM.—The compounds of selenium behave exactly like the compounds of sulphur towards the plate of silver and the glass of silica described in the last two experiments.

But when the compounds of selenium are fused with soda on charcoal in the reducing flame, they exhale the odour of horse-radish by which they are sufficiently distinguished from the compounds of sulphur.

MINERAL ACIDS.—A substance suspected to contain a mineral acid is fused with soda upon platinum foil. The fused mass is dissolved in water, filtered, saturated with acetic acid, and tested with a solution of acetate of lead. All mineral acids, nitric acid alone excepted, give a precipitate when thus examined.

E, SUBSTANCES WHICH SODA NEITHER FUSES NOR REDUCES.

The oxides of Uranium	Alumina
The oxides of Cerium	Magnesia
Tantalic acid	Lime
Zirconia	Strontian, Barytes } The *carbonates* of these earths fuse.
Thorina	
Yttria	All the Alcalies, which sink into the charcoal.
Glucina	

FIFTH OPERATION.

FUSE THE SUBSTANCE WITH MICROCOSMIC SALT.

OBJECT.—To see what coloured glass it gives.

METHOD.—Microcosmic salt, or the phosphate of soda and ammonia, is resolved by ignition into biphosphate of soda, a flux, which, in consequence of its excess of acid, has the power of fusing almost every chemical compound except silica. The latter softens and swells, but remains expanded in the fused flux like a species of skeleton. Microcosmic salt is commonly fused upon charcoal, on which it readily forms a round colourless transparent

74. Repeat this experiment with very small quantities of sulphate of soda, sulphate of lime, sulphate of copper, and with any of the sulphurets. Commence with a quarter of a grain of the sulphate or sulphuret, and repeat the experiment with smaller quantities, till you find the least portion that gives a decided result.

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bead. (See the figure on page 123.) It cannot be conveniently used on the platinum wire in consequence of its extreme fusibility, and the readiness with which it falls from the ring. When metallic oxides are fused with microcosmic salt, the resulting bead is exposed alternately to the oxidating and reducing flame, because several metals which are susceptible of being oxidized in different degrees, communicate different colours to the flux, according to the flame employed. A substance exposed to the outer flame becomes more highly oxidised, and when brought into the inner flame, becomes more or less reduced. And when the different oxides have different colours, the flux is coloured accordingly.

A bead that has been heated in the reducing flame requires to be cooled quickly on removal from the flame; because slow refrigeration induces a partial re-oxidation. This rapid cooling is most easily effected by a current of cold air blown upon the bead from the blowpipe.

The re-action expected from reduction can frequently be expedited by plunging into the hot melted bead, just after withdrawing it from the reducing flame, the end of a small roll of tin foil, (page 127,) and then again applying the reducing flame for a second or two. This has on many metals the same effect as the long-continued action of the reducing flame. By this expedient, for example, a minute portion of copper in a bead can be easily reduced to the protoxide or to the metallic state.

Oxides which are difficult of reduction, and which cannot be converted into other oxides, commonly produce the same colours in both flames.

Most oxides produce colourless beads; but a great excess of any oxide generally gives the bead the appearance of white enamel, particularly when it is cold. Still, the number is considerable of the metallic oxides, which, on fusion with microcosmic salt, produce *coloured* beads; and for oxides of this sort microcosmic salt is a most useful re-agent.

It is sometimes difficult to determine the colour of the bead. The depth of tint depends upon the quantity of the colouring matter dissolved in it. Sometimes it is necessary to add more of the colouring matter. Sometimes the bead is coloured too intensely, and appears black. In such a case, the bead, when hot, can be squeezed flat with the pincers, or drawn out to a thread, or a portion of it can be melted with a fresh quantity of microcosmic salt. The colours of many beads change as they cool. Of others, the colours vary with day light and candle light, and often the colour of a bead can be best seen at night, by holding it *beyond* the candle, and not between the candle and the eye.

The colours of beads producible with microcosmic salt are shown in the Table at pages 178, 179.[75]

75. The whole of the experiments respecting the coloured beads produced with microcosmic salt and borax, should be repeated without omission, unless the sub-

SIXTH OPERATION.

FUSE THE SUBSTANCE WITH BORAX.

OBJECT.—To see what coloured glass it gives.

METHOD. See page 125.—Nearly all substances dissolve when fused with borax, though some dissolve in it much more readily than others.

The *substances which dissolve in borax* are these:—1. All earths, metallic oxides and metallic acids, except those of gold and platinum, which too readily undergo reduction; and those of mercury, which vaporise. 2. Salts of metals, after having had their acids destroyed by ignition. 3. Metallic sulphurets, after being well roasted to drive off the sulphur. 4. Carbonates and nitrates, the acids of which are expelled during the fusion. 5. Borates and phosphates, which fuses with the flux without suffering decomposition. 6. The compounds formed by chlorine. iodine, bromine, and fluorine with metals, (chlorides, &c.,) or with metals and oxygen, (chlorates, &c.)—all of which behave pretty much like oxides. 7. Silicates, though sometimes slowly.

Sulphates, sulphites, seleniates, and selenites, suffer decomposition when fused with borax; but form beads coloured so deeply yellow or brown by sulphuret or seleniuret of sodium, that the action of the borax upon the metal cannot be observed.

Substances insoluble in borax. Reguline metals, alloys, and metallic sulphurets.

The platinum wire is the best support for borax, which melts readily in the ring, without being so fusible as to fall from it when in the state of a bead. Upon charcoal, borax cannot be fused to a bead without difficulty, and the colours cannot be so conveniently examined as when in beads upon the wire. Many metals communicate to borax the same colours as to microcosmic salt—but this is not always the case. The beads of borax, like those of microcosmic salt, change colour in the inner and outer flame. Several substances give clear beads with borax, which remain clear when cold, and even when greatly overcharged with matter; but have nevertheless the singular property of changing to an opaque enamel, when gently heated by the oxidating flame applied intermittingly. This intermitting application of heat is best managed by keeping the oxidating flame quite steady, as exhibited in the figure following on the following page, and changing the position of the wire *b*, by first

stances are such as cannot be procured, namely, yttria, thorina, vanadium, &c. The experiments are easy to be made, and the results such as it is highly necessary for the chemist to be acquainted with.

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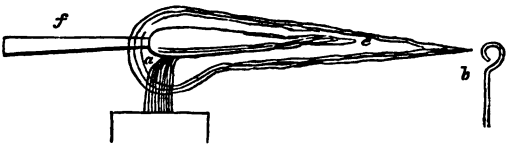
raising the bead half an inch *above* the point of the flame, then bringing it down to the *level* of the flame, then sinking it half an inch *below* the flame; then afterwards raising it gradually, first to the level, and then up above the flame, and so on alternately.



The production of colours in beads formed with borax in the oxidating flame can sometimes be facilitated by the addition of saltpetre. A small slender crystal of this salt is supported near the lamp, as on the projection marked *d* in the figure on page 113; and when the bead is removed from the flame, it is instantly pressed upon the crystal of saltpetre. The bead immediately swells and foams, and the oxidised metal exhibits its colour on the edges of the froth thus formed. By this expedient a portion of manganese so minute as otherwise to pass notice, can be readily detected.

The colours of Beads produced by various metals with borax, are exhibited in the Tables at pages 180, 181.

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COLOURS OF BEADS OF MICROCOSMIC SALT,

PRODUCED IN THE

OXIDATING FLAME.

Colourless

- Barytes, Strontian, Lime, Magnesia, Glucina, Yttria, Thorina, Zirconia — The whole of these when added in excess, produce a glass which is milk-white when cold. When carbonates are acted upon, they discharge carbonic acid with effervescence.
- Alumina.
- Molybdic acid — The colour is greenish, especially while hot. It can only be got colourless on the platinum wire, and not always that way.
- Tungstic acid, Antimonious acid — Both a little yellow.
- Tellurium.
- Tantalic acid — Does not become opaque when cold, by which character it is distinguished from the earths.
- Titanic acid — With an excess, yellow while hot.
- Zinc, Cadmium, Lead — An excess of these three gives a milk-white bead when cold.
- Tin.

Green

- Chromium — Reddish while hot; green when cold.
- Uranium — Yellow while hot; green when cold.
- Copper — Green while hot; blue when cold.
- Molybdic acid — Pale when cold; colourless on the wire.

Yellow

- Silver — Opalescent when a great excess is present. Colour reddish by candle light.
- Bismuth — Becomes nearly colourless when cold. A great excess produces an enamel.
- Vanadium.
- Uranium — Yellow while hot; green when cold.

Red

- Cerium, Iron, Nickel — Of these three metals the colour is seen best while the bead is hot. It gets very pale as it cools. The addition of tin to the bead containing iron, changes its colour to blueish-green.

Blue

- Cobalt.

Violet

- Manganese — The addition of saltpetre assists the production of this colour. The addition is made by pushing the point of a small crystal of saltpetre into the fused bead of manganese.

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COLOURS OF BEADS OF MICROCOSMIC SALT,

PRODUCED IN THE

REDUCING FLAME.

Colourless
- Barytes, Strontian, Lime, Magnesia, Glucina, Yttria, Thorina, Zirconia, Alumina, Tantalic acid, Zinc, Cadmium, Tin. — All behave the same as in the oxidating flame.
- Cerium — Red in the oxidating flame.
- Manganese — Violet in the oxidating flame.

Green
- Molybdic acid — Dark blue and opaque while hot. Greenish white in oxidating flame. Tin deepens the colour in the reducing flame.
- Chromium — Same in oxidating flame.
- Vanadium — Brownish while hot; green when cold; Yellow, in oxidating flame.
- Uranium — Same in oxidating flame.
- Iron — Red in oxidating flame.

Red
- Tungstic acid containing Iron. If tin is added, the bead becomes blue, or if much iron is present, green.
- Antimonious acid containing iron.
- Titanic acid containing iron. — The addition of tin changes it to violet.
- Nickel — The colour of this bead becomes pale as it cools. It gives the same colour in both flames, by which it is distinguished from iron. If tin is added, it first becomes grey and opaque, and then colourless.

Brown
- Copper — The bead is opaque. In the oxidating flame it is green and transparent. The addition of tin promotes the reduction. Too much tin precipitates all the copper, and the bead becomes colourless.

Blue
- Cobalt — Same in both flames.
- Tungstic acid — Yellowish white in oxidating flame. If iron is present, red in the reducing flame. The addition of tin destroys the action of the iron.
- Molybdic acid — Blue when hot; green when cold.

Violet
- Titanic acid — Yellow while hot. Becomes red and violet as it cools. Colourless in oxidating flame.

Grey
- Tellurium, Bismuth, Lead, Silver, Antimony — The grey colour is owing to the presence of reduced metal. The beads sometimes become clear in consequence of the entire separation of the metals.

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COLOURS OF BEADS OF BORAX,

PRODUCED IN THE

OXIDATING FLAME.

Colourless	Barytes, Strontian, Lime, Magnesia, Glucina, Yttria, Zirconia, Tantalic acid, Titanic acid, Zinc, Cadmium, Silver.	The saturated beads of these twelve substances, produce opaque enamels when heated with an intermitting flame.
	Alumina, Thorina, Silica, Tellurium, Bismuth.	
	Antimony.	Yellowish while hot.
	Tungstic acid.	Yellow while hot, with a great excess.
	Molybdic acid.	Yellow while hot, or with a great excess red while hot, and a blueish enamel when cold.
	Tin.	
Green	Chromium.	Red while hot; becomes yellow and then green, as it cools.
	Copper.	Green while hot; blue when cold.
Yellow	Vanadium.	
	Uranium.	Gets pale as it cools. With an excess, becomes opaque when heated with the intermitting flame.
	Lead.	Nearly colourless when cold.
Red	Cerium.	Reddish-yellow while hot; yellow when cold. Becomes opaque when heated by the intermitting flame.
	Iron. Nickel.	Become yellow as they cool, and nearly colourless when cold. The addition of saltpetre makes the Nickel glass blue, but not the Iron glass.
Blue	Cobalt.	
Violet	Manganese.	Appears black with an excess.

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COLOURS OF BEADS OF BORAX,
PRODUCED IN THE
REDUCING FLAMES.

Colourless	Barytes. Strontian. Lime. Magnesia. Glucina. Yttria. Zirconia. Tantalic acid. Zinc. Cadmium. Alumina. Thorina. Silica. Tin.	All these are also without colour in the oxidating flame.
	Cerium.	With excess white and crystalline. Red in the oxidating flame.
	Manganese.	Violet in the oxidating flame. The reduced bead acquires a colour if not quickly cooled.
Green	Chromium.	Green both hot and cold; but in the oxidating flame, it is red when hot, and green when cold.
	Vanadium.	Brown while hot, green when cold. Yellow in the oxidating flame.
	Uranium.	Blackened by an intermitting reducing flame. Yellow in the oxidating flame.
	Iron.	Red in the oxidating flame.
Yellow	Tungstic acid.	Darker in colour as it cools, red with excess, tin renders the glass milky when cold. Colourless in the oxidating flame.
	Titanic acid.	Yellow while hot, violet when cold.
Reddish-Brown	Molybdic acid.	Colourless in the oxidating flame.
	Copper.	Green in the oxidating flame; metallic tin assists the production of the opaque brown bead. See page 175.
Blue	Cobalt.	Same in the oxidating flame.
Violet	Titanic acid.	Yellow while hot, violet when cold, becomes opaque if heated with the intermitting flame. Colourless in the oxidating flame when hot, but white enamel when cold.
Grey	Antimony. Tellurium. Nickel. Bismuth. Silver.	In consequence of the presence of reduced metal.

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MINERALS FOR ANALYSIS.

As no one can become master of the blowpipe without a good deal of exercise, and as materials for working upon are necessary for that purpose, I recommend to the reader's notice a small CABINET OF MINERALS, which may be procured, at the cost of half-a-guinea, from Messrs. RICHARD GRIFFIN & Co. Glasgow. It is known by the title of "GRIFFIN'S COLLECTION OF MINERALS FOR EXAMINATION BY EXPERIMENT: comprising fifty-four important minerals, selected from various classes, and adapted to different modes of Analysis by Chemical Tests and the Blowpipe." The names and localities of the specimens contained in this Cabinet are as follow:—

1. QUARTZ, Schwalback, Nassau
2. TABULAR SPAR, Hermala, Finland
3. PLASTIC CLAY, Wiesert, Hesse
4. AMIANTHUS, Sterzing, Tyrol
5. CYANITE, Zillerthal, Tyrol
6. TOPAZ, Brazil
7. ALLOPHANE, Better, Hungary
8. MICA, Aschaffenberg, Bavaria
9. LEUCITE, Vesuvius
10. FELDSPAR, Hembsbach, Baden
11. ALBITE, St Gotthardt, Switzerland
12. SCHORL, (*Black Tourmaline,*)
13. MESOTYPE, Seisser Alps, Tyrol
14. PUMICE, Isle of Lipari
15. LEPIDOLITE, Moravia
16. CALCAREOUS SPAR, Iceland
17. BITTERSPAR, Zillerthal, Tyrol
18. PHOSPHORITE, Amberg, Bavaria
19. FLUOR SPAR, Schriesheim, Baden
20. ANHYDROUS GYPSUM, Sulz, Wirtemberg
21. GYPSUM, Luneburg, Hanover
22. MAGNESITE, Bandissero, Piedmont
23. HEAVY SPAR, Schriesheim, Baden
24. CŒLESTINE, Jena, Saxony
25. ROCK SALT, Hall, Wirtemberg
26. ALUNITE, Tolfa, Italy
27. OXYDULATED IRON, Arendal, Norway
28. MISPICKEL, Freiberg, Saxony
29. IRON PYRITES, Dillenberg, Nassau
30. MAGNETIC IRON PYRITES, Bavaria
31. RED IRON ORE, Ilefeld, Harz
32. SPECULAR IRON, Isle of Elba
33. BROWN IRON ORE, Amberg
34. SPATHOSE IRON, Biber, Hesse
35. CLAY IRONSTONE, Wiesert, Hesse
36. GREY MANGANESE, Ilefeld, Harz
37. OXIDE OF TIN, Altenberg, Saxony
38. NATIVE BISMUTH, Schneeberg, Saxony
39. NATIVE ARSENIC, Andreasberg
40. REALGAR, Kapnik, Hungary
41. GREY COBALT, Bieber, Hesse
42. SULPHURET OF NICKEL, Ebersdorf
43. GREY COPPER, (*Fahlerz*), Siegen
44. COPPER PYRITES, Dillenberg, Nassau
45. MALACHITE, Siberia
46. SULPHURET OF ANTIMONY, Wolsberg
47. GALENA, Freiberg, Saxony
48. CARBONATE OF LEAD, Freiberg, Saxony
49. PHOSPHATE OF LEAD, Hofsgrund, Baden
50. ZINC BLENDE, Harz
51. SILICATE OF ZINC, Siberia
52. CINNABAR, Mosche Deux Ponts
53. SULPHUR, Bex, Moravia
54. ANTHRACITE, Ebersdorf, Saxony

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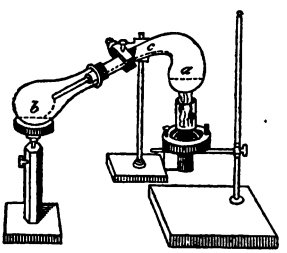
DISTILLATION.

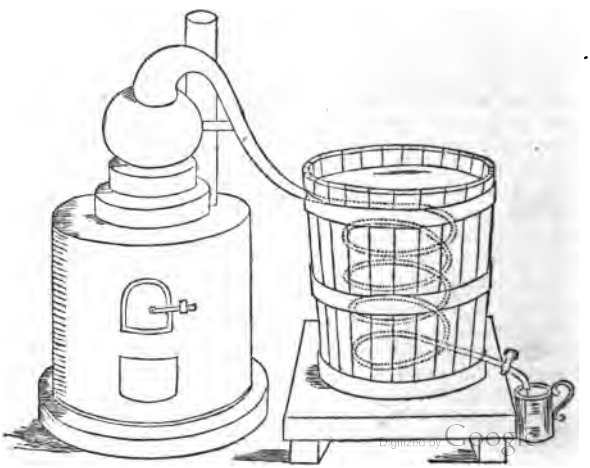
As the fluid carried off in the state of vapour, during evaporation, is entirely lost, being sacrificed for the sake of the fixed substance with which it was combined, and which remains behind, that process is only employed when the fluid is of little value. But, when the fluid is of sufficient consequence to be preserved, we have recourse to *distillation*, which may be defined a chemical operation whereby a volatile substance is separated from less volatile substances, and the volatilised portion is collected for use.

Solid sulphur becomes liquid when strongly heated, and if raised to the temperature of 600° F. it *boils*, behaving in that respect as water does at the temperature of 212° F., whereat that liquid changes the fluid for the gaseous state, and instantly expands in bulk no less than seventeen hundred times. Admitting sulphur to expand in like manner, if not in like degree, a small piece of that substance must be considered to be sufficient to fill a large vessel with vapour of sulphur, and experiment proves this to be the case. For example, when sulphur is boiled in a glass retort, *a*, over a spirit lamp, a very small quantity of the solid substance suffices to fill the entire vessel with gaseous sulphur. If a considerable quantity of sulphur is placed in the body of the retort, and exposed to heat, gas continually rises from it as the boiling proceeds. This gas gradually forces the atmospheric air out of the retort, and presses after it down the neck, *c*, of the retort. This neck, being beyond the heating influence of the spirit lamp, is kept in a cool state by the surrounding air. The consequence of this is, that the gaseous sulphur which presses down the neck, soon reaches a situation when the temperature is below 230° F. Arrived there, it loses its gaseous form, and is deposited upon the glass in a fine powder, communicating, as it falls, a certain degree of heat to the glass. This production of gas in the body of the retort, and deposition of powder in its neck, continue till the entire retort becomes sufficiently hot to allow the sulphur to flow from its mouth in the *liquid* state. The powder previously deposited in the neck then melts and runs out. If the heat is continued, the whole of the sulphur which was put into the retort is thus gradually converted into gas, and the gas condensed in the neck into a liquid which flows thence into the receiver *b*. When the sulphur thus distilled has been previously mingled with clay, sand, or other substance not susceptible of volatilisation by heat,



such substances remain in the retort after the sulphur has been entirely expelled. We see, therefore, in this experiment, in what manner substances which differ in their volatility, and of which some are easily raised in vapour by heat, and as easily again condensed by cold, and others not so, in what manner such substances can be separated from one another by the operation of *Distillation*.

I shall here shortly describe several methods by which this operation is effected both with small quantities and in the large way, premising only, that so far as the large way is concerned, the description here given is not to be considered as full instructions for the guidance of practical persons, but simply as a theoretical explanation of the operation for the instruction of the chemical student:—The vessel usually employed for distillation, in the large way, is called a *still*. It consists of a copper vessel, of the shape of a tea-kettle, but without its spout and handle, enclosed in the brick-work of a furnace. Into the opening of this vessel, instead of a common lid, a capital or moveable head is affixed, which ends in a narrow open pipe. This pipe is received into what is called a *worm*, which is a tube of lead, twisted spirally, and fixed in a wooden tub, so that it may be surrounded by cold water. When the apparatus is to be used, the liquid intended to be distilled is put into the body of the still, and the head is fixed in its place, the pipe, which terminates it, being received into the leaden worm. A fire is then kindled in the furnace, and the liquid is made to boil as rapidly as possible. It is thus raised into vapour, which passes into the worm, is there condensed by the surrounding cold water, and flows out of the extremity of the pipe into the vessel placed to receive it.



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The last print very well represents the old form of the still and its worm-tub, such as it is at this day to be seen in many distilleries; but other forms have been contrived, both of the still and the condensing apparatus, which greatly accelerate the operation of distillation, and add considerably to the profits of the business. It is proper for me to explain these improvements, not only that you may know the new as well as the old method of working, but that you may have an example of the apparently *slight* alterations by which a trade of vast extent is often wonderfully benefited.

The first modern improvement upon the STILL was upon the shape of the *boiler*, which, instead of being formed upright and narrow, like the body of a tea-kettle, was made more nearly to resemble a stew pan, being diminished in height and increased in breadth till it exhibited the proportions of the following figures:—

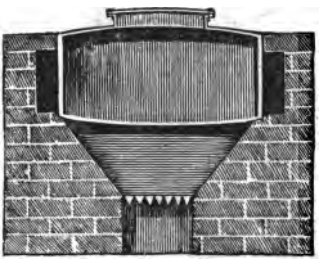

Fig. 1.

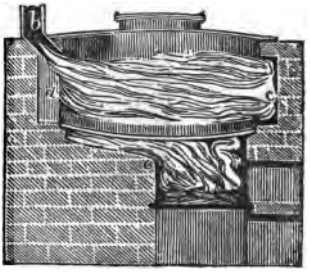

Fig. 2.

The reason for this change was the proof afforded by experience, that evaporation was effected, with the same expenditure of fuel, more rapidly in broad shallow vessels than in deep narrow ones.

The next improvement made was upon the form of the *fire-place*, which was modified in such a manner as to apply the heat produced by the consumption of the fuel, as directly and as effectually as possible to the boiler. With this view the boiler was so placed amid brick-work, above the fire-place, that the flame of the fuel, after striking directly upon its bottom, was forced to rise up on one side and pass entirely round the body of the boiler before it reached the chimney; the boiler being supported in its place by the resting of a portion of its edge upon the brick-work of the fire-place. Fig. 1, is a section of the boiler and fire-place as seen in front, and fig. 2 is a section of the same seen sideways. The latter also exhibits the direction of the flame, which, after playing upon the bottom of the boiler, passes by *e*, into the flue that is built round the boiler, and runs in the direction *c*, *a*, into the chimney *b*. The advantage of this form of the still and fire-place is, that the greatest evaporation

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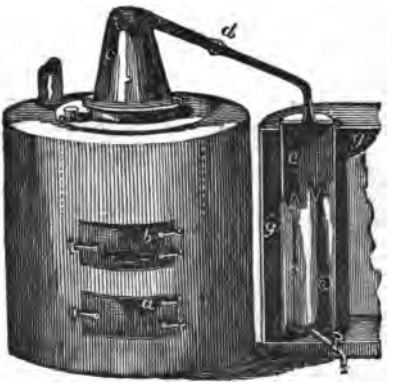
takes place in the least space of time, and with the smallest expense of fuel.

I now come to describe an improvement made on the form of the *head* of the still, the apparatus intended to convey the steam from the boiler to the condenser. In practice, it was found that the *globular head*, shown at page 184, acted in some degree as a condenser, being so much cooled by the surrounding air as to re-convert a portion of steam into liquor before it reached that part of the pipe which could carry it into the condenser. The result of this cooling was that this liquor ran back into the boiler, and had to be re-converted into steam, at a fresh expenditure of time and fuel. This drawback upon the rapidity of



the process, was remedied by the adoption of a head, having a conical or sugar-loaf shape. The above figure represents a still fitted up with the improved head, *c*, from the summit of which a pipe, *d*, descends at an acute angle to the condenser, *e*, *e*, which, in this case, is a perpendicular cylinder, and not a worm. The cold-water apparatus, answering to the worm tub, is represented here by *g*, *g*. The fire-place is at *b*, and the ash-pit at *a*. The chimney is seen behind the head.

The worm-shape, as it may be inferred from the description of the last figure, is not *essential* to the condenser, though its occurrence is so common. Any form of vessel that can be kept cool by the continual application of cold water to its outer surface, answers the requisites of a condenser; and extremely diversified are the forms of vessels that have been contrived for this purpose. The last improvement which I shall notice on distilling apparatus, is the combination of vessels that appears to answer best the purposes of cheap and rapid condensation. A figure of this apparatus is given in the following page. The pipe *a* leads from the head of the boiler into a close

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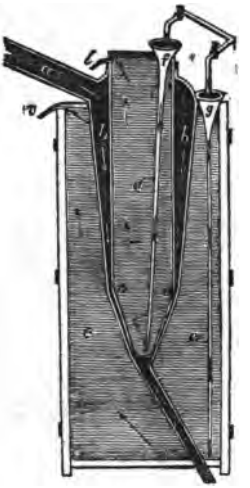
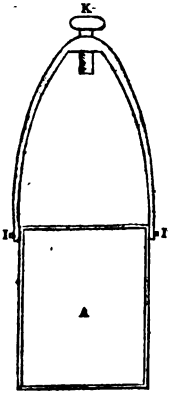
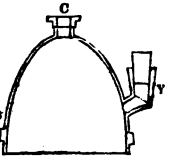
vessel, *b*, *b*, terminating in the pipe *c*. This close vessel is hollow. It is surrounded by a vessel filled with cold water, *e*, *e*, and the hollow within it is occupied by another vessel filled with cold water. The form, relative size, and position of these different vessels is shown by the section. There is an excellent provision for keeping the vessels always full of *cold* water. A pipe, open at bottom, and surmounted by a funnel, is fixed in each cold water vessel, through which, from the stop-cock above, to the bottom of each vessel, there passes a constant stream of cold water; while the water, which, by condensing the steam, has become warm, rises spontaneously to the top of the cold water, and flows gradually out of the vessels by the apertures *v* and *l*. An admirable practical application is made here of the scientific principle that water becomes light as it becomes warm, and the application is found to be most profitable in the business we are considering.



Description of a Still adapted for the separation of alcohol from wines, and for use in other analytical inquiries, contrived by DESCROISELLES *and* GAY-LUSSAC.



This apparatus is composed of a small cylindrical copper still, A, about 4 inches high and 3½ inches wide, surmounted by a capital, or dome, B, which is open at its upper part, C. This opening is intended to receive the extremity, D, of the tube E, of which the other end forms a worm in the refrigerant, F, and terminates in an orifice at G, as represented in the figures in the following page.



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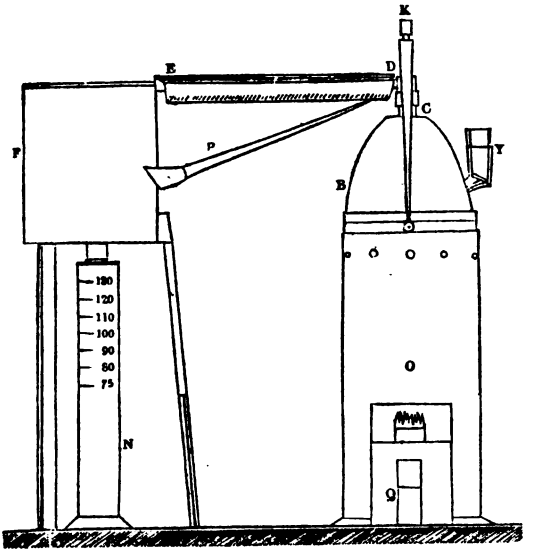
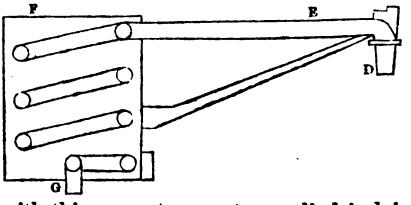


The following cut exhibits a section of the refrigerant F, and of the coiled tube D, E, G.



Connected with this apparatus are two cylindrical jars on feet similar to figure N—one of them graduated into 300 divisions, the other into about 130 divisions. These jars should be about 6 inches high; the larger 1½ inch wide, the smaller 1¼ or 1 inch wide.

In using this still, you commence by filling the larger jar with the wine for analysis up to the division 300. This wine you pour into the still, to which you then adapt the dome B and refrigerant F, fixing the tube E in its place at D by means of the screw K, which passes through a moveable iron handle that is fastened to each side of the still at I, I. The still is placed within an iron cylinder, O, and heat is applied by means of a spirit lamp, Q, similar to that described at page 18.

The jar N is placed below the refrigerant, and serves to collect

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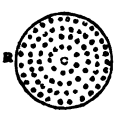
the alcoholic product of the distillation as it escapes from the pipe G. It is necessary to be careful, during the distillation, to keep the refrigerant supplied with cold water, and continually to wet the cloth which envelopes the tube between E and D. The water which drops from this cloth is collected by the gutter P, and carried to the little reservoir at its lower end.

The distillation is arrested when the product in the jar N amounts to 100 divisions, or to one-third in bulk of the wine submitted to analysis. This distilled product consists of alcohol and water, the relative proportions of which are determined by taking its specific gravity, either by weighing in a thin bottle or by means of the hydrometer. The proportion of alcohol being ascertained, the number is divided by 3, to find the per centage of alcohol of the wine submitted to analysis.

Thus, for example, if such an experiment yields 100 parts of diluted alcohol at 30° of the centisimal alcoholimeter, the richness of the wine is = 10°—that is to say, it is to be considered as containing *ten per cent.* of alcohol.

Whenever, through want of attention to the progress of the distillation, you happen to collect *above* 100 measures of product in the jar N, you cannot, after ascertaining the alcoholic strength of the product, determine that of the wine by simple division of the number by 3, as in the case where exactly 100 measures are collected. You have, however, still only a very simple calculation to go through, to determine the point in question. If you collect 106 divisions of product, containing 33 per cent. of alcohol, you divide this result by 3, which gives 11. This you multiply by the number of divisions obtained, namely, 106, which gives 1166, and divide this by 100, which gives 11.66. This is the per centage of alcohol of the wine.

DISTILLATION OF VOLATILE OILS.—This little still can be also employed in several other operations, as, for example, in the preparation of odoriferous waters and volatile oils, in the determination of the quantity of alcohol capable of being extracted by distillation from a mass of fermented dough, &c. For operations of this sort, it is useful to have the little piece of additional apparatus represented in the margin. It consists of a circular disc of brass, R, pierced with numerous small holes, supported on three legs about $\frac{1}{4}$ of an inch long, and having a single rod as a handle on its upper side. By means of this handle it can be introduced into the still, A, or withdrawn at will. The solid substances intended to be distilled are placed upon this disc,



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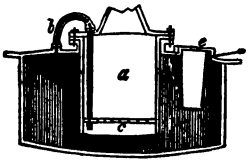
and the whole apparatus is put together, as before directed, for distillation. A quantity of distilled water is next put into the graduated pipette, S, which is then adjusted in the opening, Y, of the dome, B, (page 187,) by means of the cork, U, fixed on the lower point of the pipette, of which the upper extremity is closed by the cork, T.

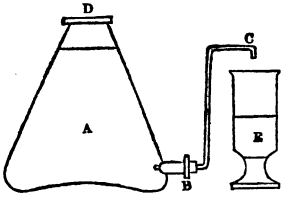
The apparatus being thus arranged, the cork, T, is loosened, and a small quantity of water is introduced to the substance to be distilled. The cork, T, is then fixed tight. This water reaches the bottom of the still through the holes in the brass disc, R, and being, on the application of heat, converted into steam, it ascends and acts upon the substance placed upon the disc. Whatever this solid substance contains of alcohol or volatile oil, is then extracted and carried off by the steam. When the first quantity of water applied has passed off in distillation, a second portion is added as before, by loosening the cork, T, and this is continued until it is imagined that the substance in the still is entirely exhausted of alcohol or of oil. This disposition of apparatus has the double advantage of preventing the burning of solid vegetable matter which occurs when it is placed immediately upon the bottom of a still, and of more completely effecting the separation of its volatile parts than it is possible to do when the substance is simply boiled in a quantity of water.

The following is another method of distilling volatile oils, as described by MITSCHERLICH, in connection with the large still figured on page 186. A cylindrical vessel, *a*, is hung in the still; a sieve, *c*, is fixed a little way above the bottom of the cylindrical vessel; and the vegetable to be distilled is placed upon the sieve. The edge of this vessel rests on the edge of the still, and is so arranged that it can be screwed air tight to the still-head. The flat top of the still is provided with a hole, and there is another hole in the head of the still. Through both of these holes the bent tube, *b*, passes, and one end of it descends below the sieve, *c*, in the cylindrical vessel. When the water in the still is boiled, the steam necessarily rises through the pipe, *b*, descends below the sieve, *c*, and thence rushes through the vegetable substances in its way to the head and the condenser. The narrower and longer the vessel *a* is made, the more effectually is the vegetable substances which are placed in it exposed to the solvent action of the current of steam.



The liquid which flows from the pipe of the condensing apparatus, in an operation of this kind, is a mixture of water and oil. These liquors, upon reposure, separate, and the whole of the oil swims upon the surface of the water, excepting a certain quantity, which is dissolved and retained in solution by the

water—a quantity variable with different species of oil and at different temperatures. The apparatus usually employed in the separation of water from oil is termed the Florentine receiver. It is represented in the margin. A is a conical bottle, having a tubulure, or mouth, B, near the bottom. A bent glass tube, C, is fixed in this mouth by means of a cork, B. During the distillation, oil and water flow together into the mouth D, of the bottle A. They gradually separate there, as the mixture cools, and the oil rises to the top of the water. When the level of the mixed liquids in the vessel A, rises above the height of the tube C, the water runs through C till the level in the vessel is reduced to the height of C, at which it remains unaltered—water then issuing constantly from the pipe C, in proportion as additional fluid comes into the vessel at D. The water which thus issues from the tube C is collected in the vessel E. The widening of the vessel A is for the purpose of retaining the water a sufficient time to allow the oil to separate from it as completely as possible.



After all, however, the water thus separated is a saturated solution of the oil that has been distilled. When, for example, lavender is thus treated, the oil obtained is *oil of lavender;* the water thus separated is *lavender water*. Nearly all odoriferous waters are prepared in this manner for the use of the perfumer and the druggist, although it is possible to make them directly by mixture of the oils with water. The mixtures termed *esprits* by the perfumers differ from these scented waters simply in the substitution of alcohol for water: *esprit de lavande* is a solution of oil of lavender in diluted alcohol, and so on. In general, these *esprits* are prepared by distilling the various plants, in the manner described above, with whisky, gin, or brandy, instead of water.

The following method of separating volatile oils from water may be employed where the Florentine receiver is not at hand. The mixed liquids are to be received in a cylindrical vessel. When the latter is nearly full, a syphon is to be used to draw off the water. To this end, the long leg of the syphon is put into the cylindrical vessel, and a current is produced by sucking with the mouth at the end of the short leg. The water runs off till the surface of the liquid in the cylindrical vessel descends to the level of the mouth of the short leg of the syphon. The current then stops, but in proportion as fresh mixed liquid arrives in the vessel from the still, a corresponding proportion of water escapes by the outer leg of the syphon.

A third species of receiver, adapted for this purpose, is a stone jar, having a mouth at the top, in the manner of a *greybeard*, and another mouth at the side, near the bottom, to which a tube

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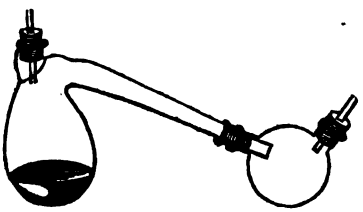
can be adjusted in the same manner as to the Florentine receiver. Two-necked jars of this description, and which, as are to be shown presently, are useful for supplying a stream of water, and other purposes, are now to be had in Glasgow at a very moderate price. The price of a jar of one quart capacity is 1s.

DISTILLATION IN RETORTS.—The common still, in all the foregoing varieties, can only be employed in the large way, or in the distillation of such liquors as do not suffer injury from the copper, tin, lead, or other metal which enter into the construction of the still or cooler. The vessel which is most employed by the philosophical chemist in the operation of distillation, is the *retort*. This is a pear-shaped vessel of glass, similar in form to the figure given below. In the top of the body, or wide part, is an opening, or tubulure, through which the materials to be distilled are inserted. This opening can be closed by a cork or by a glass stopple, ground so as to be air-tight. Retorts are sometimes made without the opening at the top, as is that figured in the description of the distillation of sulphur, page 183. They are then cheaper, and are called *plain* retorts; but those with the opening, called *tubulated* retorts, are, in some cases, more convenient, though they are liable to the inconvenience of cracking at the tubulure, especially when the latter is put on clumsily, like a thick lump of glass. Retorts are also made of porcelain and of platinum.



A necessary appendage to the retort, is a *receiver*. The retort is the vessel in which a liquid is raised into vapour. The receiver is the vessel in which the vapour is again condensed into the liquid state. The receiver is a vessel of glass, generally of a globular form, though not always so. The annexed figure represents a tubulated retort, connected with a tubulated receiver. The tubulure of each of these vessels is represented as being stopped with a cork provided with a glass tube. Sometimes the neck of the retort is much too small to fit closely the neck of the receiver. In that case, a cork must be provided that fits the latter, and must have a hole burned or bored through it, of a sufficient size, to hold the former. The plan with a cork will not answer, however, when corrosive fluids are distilled. You must then use an instrument of glass, called an *Adapter*. This consists of a glass tube, shaped like a rolling-pin, one end of which takes in the mouth of the retort, and the other end of which goes into the mouth of the receiver. The joinings are secured by cement.

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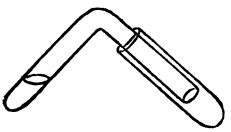
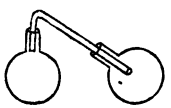
Sizes of Glass Retorts.—The sizes of retorts most generally useful to a student are those of 2, 3, 4, and 8 oz. capacity, and for occasional use, one that holds a pint. The 2 oz. and 4 oz. plain and tubulated are to be preferred. They answer best when made of hard glass, but flint glass can nevertheless be used, excepting in dry distillations for the preparation of gases, &c., for which purposes hard glass is indispensable. In such operations, it is in general most advisable to use very small distilling vessels. The little tube vessels described at pages 8—10, serve both as retorts and receivers, in a great number of cases; and the student who can use the blowpipe, is able to modify their forms with facility.

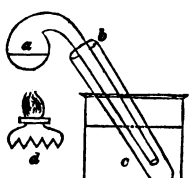


The simplest of all such minute retorts and receivers are those formed of small tubes without bulbs, which can be set together in the manner shown by the figure. They are extremely useful in small experiments. The bent tube is, of course, the retort, and the straight wide tube the receiver.

In some cases the retort answers best when made of the annexed form, especially when the purpose to be effected is a dry distillation.



The annexed figure exhibits another form of distilling apparatus, which may be employed when small quantities of substances are operated upon. It consists of two small bulbs, blown out of a glass tube by means of the blowpipe. One serves for a retort, and the other for a receiver, and the two are connected by a narrow glass tube.



Here is another apparatus of like kind. *a* is the retort, *b* a receiver formed of glass tube, *c* a vessel of cold water, acting the part of a worm-tub. It is easy to connect *a* to *b* loosely, by a cork or a fold of paper. *d* is the flame of a spirit-lamp.

As the operator's command of heat is always very great in respect to these small retorts, the economical considerations which are of so much importance in reference to the form of *the still*, are in this case of no consequence. That form of small retort is best, which is easiest to make and easiest to clean; which most readily permits the insertion of the charge, and can be best connected with the condenser.

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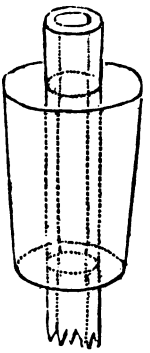

In many cases, a flask can be employed, instead of the retort, as a distilling vessel, connecting it with the receiver, by means of a bent glass tube. The figure in the margin exhibits a piece of tube of the size and strength commonly employed in operations of this nature, and which is passed through a perforated cork of the size necessary to fit the mouth of an ordinary flask. This species of tube is very much employed in the conveyance of *gases*, from the vessels in which they are generated into those prepared for their reception.

Porcelain Retorts.—For certain experiments, which require a high temperature, retorts of porcelain are required. Those of the best quality are made at Berlin. They are rough on the outside, but glazed within. There are three sizes in common use, the prices of which in Glasgow are as follows:—

No. 1,—	7 inches long,	3s.	plain,—	4s.	tubulated.
2,—	9 do.	4s. 6d.	do. —	6s.	do.
3,—	16 do.	7s. 6d.	do. —	10s. 6d.	do.

In general the operations for which these porcelain retorts are used, require so high a temperature that the aid of a furnace is necessary. The heat requires to be raised gradually to prevent the splitting of the retort, and it should be as gradually reduced. The Berlin porcelain retorts will, however, undergo without injury such changes of temperature as immediately destroy any other variety of porcelain.

Retort and Receiver combined.—The annexed figure exhibits the bent tube employed by Dr Faraday, to supply the place both of retort and receiver. When a liquid is boiled at the bottom *a*, the vapour it produces can be condensed at the bend *b*, by the external application of cold water, while incondensable gases escape at the mouth *c*. Such a vessel is useful in effecting the solution of substances which dissolve with difficulty, and which require to be frequently redistilled with the same liquid, of which substances platinum affords an example. If that metal is boiled in an open flask with aqua regia, a great loss of acid is sustained before the solution of the metal is effected; while, by using this bent tube for the operation, the volatile acid can be retained,

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and from time to time be returned upon the metal by a slight movement of the vessel.

As to the way of using this little piece of apparatus in distillation, I cannot do better than describe it in the words of Dr FARADAY. (See *Chemical Manipulation*, page 396.)

"The fluid to be purified or distilled may be poured into the tube; and the latter being held upright, and the finger placed over the aperture, heat should be applied below, and vapour raised: this will condense upon the sides of the tube, and flow down, carrying with it that portion of the fluid which, in pouring it in, adhered to the side: this should be done till it is observed that the vapour rises nearly to the top before it condenses, and insures the cleansing of the whole tube. This preliminary operation is intended simply to wash the adhering portion of the introduced fluid to the bottom of the apparatus, that nothing may remain at *b* to contaminate the distilled products. The tube is then to be placed as in the figure, the proportion of the vessel and the charge being such, that the latter should not occupy more than half that part of the tube (from *a* to the first bend). Heat being then gradually applied near the top of the liquid, the latter should be distilled over into the angle at *b*, which is now to be cooled by wet paper, water, or some other means. If the distillation be unsatisfactory, it is easy to return the product, and repeat the operation."

INSERTION OF THE CHARGE INTO A RETORT.—The substances which are to be subjected to distillation should be put into the retort with care. When it has a tubulure, they are to be inserted thereby. Solid bodies ought not to be dropped in so as to fall suddenly upon the bottom of the retort, otherwise they will make a hole and fall through. The retort should be inclined, and the pieces, reduced to a small size, be allowed to slide in gently. If there is no tubulure, care should be taken, in placing the charge in the retort, not to soil the neck, otherwise the vapour which rises during the distillation, and washes the neck of the retort, will convey the impurities into the receiver. If the neck of the retort is first made very clean and dry, solid substances may be passed in without soiling it; powders should be dried before the fire and then poured through a dry and warm funnel; liquids ought to be inserted by a funnel, having a glass tube neck sufficiently long to reach into the body of the retort, and at the same time to project beyond its mouth. When a liquid has been poured through such a funnel into a retort, the funnel should be carefully withdrawn, and in such a manner that the drop of liquid resting at the point of the funnel does not touch the interior of the neck of the retort. This is best managed by holding the retort in such a position that the opening of its neck is brought rather lower than the part which joins the body of the retort. The drop then runs back into the neck of the funnel.

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The charge put into a retort ought seldom to occupy above one-third of its capacity. When a greater proportion of materials is inserted, the mass is liable to boil over.

For farther instructions on this subject, see pages 15 and 105, where I have already spoken of the precautions necessary to be taken in putting charges into glass vessels.

Application of Heat to Retorts.—The heat applied to a glass retort may be that of a spirit lamp, a gas light, or a charcoal fire. When the retort is small, and only a moderate degree of heat is required, the retort may be supported over a spirit lamp by means of the triangular retort-holder described at page 37, or still better by means of the flat ring of the lamp furnace, page 24. In general it is advisable to put between the retort and the flame a thin stratum of sand contained in a sand bath, which may either be a capsule of copper or of *ironstone*, of which description two sizes are now made in Glasgow as accompaniments to the lamp furnace. Another addition to the apparatus last named, and specially provided for the operation of distillation, is an *ironstone dome*, adapted to the top of the lamp furnace, and intended to perform the same good office of retaining heat about retorts, that the dome, *d*, figured at page 24, performs towards flasks. This new dome resembles a bee-hive, with a large door; and when placed upon the lamp furnace, it covers the whole upper part of the retort, excepting the neck; and by keeping the retort warm, prevents the condensation of vapour before it fairly enters into the neck.

The advantage derived from the use of such a dome is evident, if we consider that in distillations of this sort it is of importance that no condensation takes place in the upper part of the retort, and that the retort be so shaped that whenever condensation begins, the resulting liquid may flow into the receiver, and not return into the retort. If the latter occurs, the fuel is spent in vain, and the operation may last for weeks, as the result of the distillation is then merely a circulation between the upper part of the retort and the lower. The first wood cut that follows this paragraph shows the best form for a retort to be used in distillation over a lamp. Where the stoneware dome which I have described, cannot be procured, a cone of pasteboard cut nearly to the shape of the upper part of the retort, but somewhat larger, and fixed above the retort during the operation, may supply its place. I have in another section (page 30) described a similar contrivance for this purpose.

Of the two sand baths that I have alluded to, the smaller is adapted for the orifice of the ring-top, *c*, of the lamp furnace, page 24, and can be used with retorts of 4 oz. capacity. The larger is adapted to fit the top of the furnace cylinder, *b*, page 24, without the ring, and to receive retorts of 4 oz. to 12 oz. capacity. When this sand bath is used, the edges of the dome rests upon the sand within the capsule.

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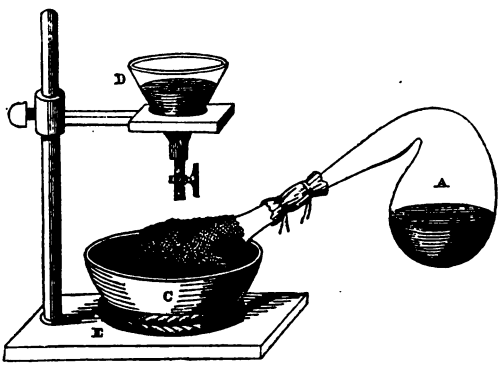
In some cases, the retort is best held by the neck, instead of being supported below. The tube holder (page 43) is adapted to support retorts of one or two ounces capacity; and Sefstroem's holder (page 39), to support larger vessels. When the retort is large, it may be exposed to the heat of a charcoal fire, or to a sand heat, by means of Luhme's furnace (page 29). If a furnace is not at command, a large gas flame (page 23), or the large spirit lamp (page 19), may answer the purpose.

BEST MEANS OF EFFECTING CONDENSATION.—In order that the vapour produced in a distillation may be condensed as fast as it comes over from the retort, the body of the receiver attached to the retort is either placed in a tub of cold water, or kept cool by the continually renewed application of wet cloths or wet blotting paper. It can also be kept cool by means of a small stream of cold water, so contrived as to run continually from the point of a little glass syphon placed in a pan of water. A refrigerant of this description is shown in the following figure, where A and B represent a retort and receiver,



E a funnel holder, D a funnel with a stop cock affixed to its neck, and C a basin. The receiver B is covered with a linen cloth, or what answers better, a nett thrown loosely together. The stop cock is only so far turned on as to allow a very small stream of water to flow out. When a stop cock is not at hand, the flow of water may be regulated by merely putting a paper filter into the funnel, and letting the water pass through the filter, or by partially obstructing the neck of the funnel by means of a cork. When the basin C is too full of water, a portion can be removed by a syphon. In some cases it is advantageous to enclose the receiver entirely in the nett, as is shown in the following cut. The water suffered to fall upon its upper part is then very effec-

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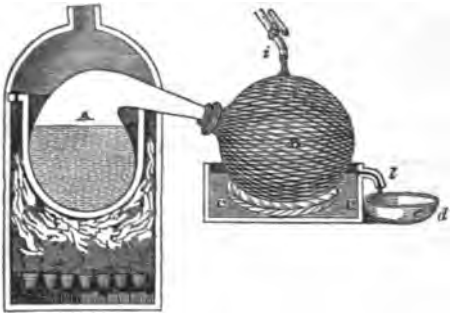
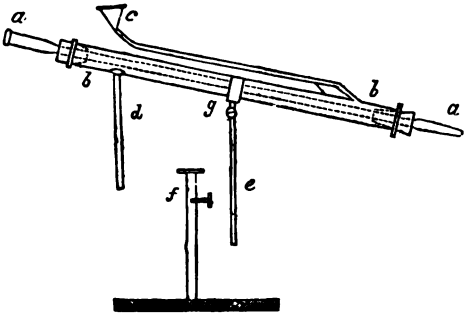
tually spread over its whole surface, and effects a complete condensation.



The best refrigerant yet contrived for use in small operations, is probably the one shown in the following figure:—



a, *a*, is a tube of glass about 30 inches long, and $\frac{5}{8}$ inch wide. The upper end is widening to admit the neck of a retort; the lower end drawn out to a narrow orifice. *b b* is a thin brass tube, 20 inches long, and about $1\frac{1}{4}$ inch wide, fastened upon the glass tube by a cork at each end. *c* is a funnel with a long brass neck, communicating with the large tube *b b* at the lower end. *d* is a brass pipe communicating with the large tube *b b* at the under side of the upper end. *f* is a hollow brass pillar screwed upon a mahogany foot. *e* is a brass rod that slides in the pillar *f*, and can be fixed at any height by the screw attached to the pillar. A brass band passes round the middle of the tube *b b*, and is connected with the rod *e* by a joint *g*, so contrived as to allow the tube *b b* to be placed at will more or less horizontally or vertically.

When water is poured into the funnel *c*, it runs through the

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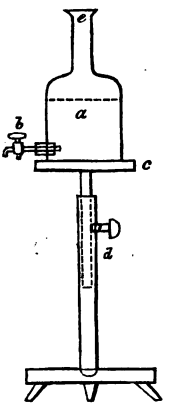
apparatus in the direction *c*, *b*, *b*, *d*, and then escapes. In its passage it wets the entire surface of the enclosed glass tube from *b* to *b*. Consequently, if the upper end of the tube *a a* is connected with a retort, and a stream of cold water is passed continually into the funnel *c*, rapid condensation takes place within the glass tube, and the liquid product of the condensation flows out at the lower end of the tube.

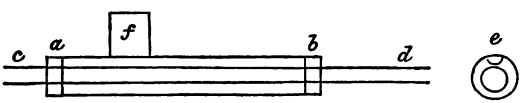
Although two or three methods of supplying a stream of cold water have been already noticed, I have yet to describe another method peculiarly adapted for use with this refrigerant. *a* is a large and strong glass water flask, 5 inches wide and 6 inches high, exclusive of the neck *e*. *b* is a stop cock fixed by means of a cork into a hole drilled in the side of the flask near the bottom. *d* is a strong wooden support for the flask, consisting of a hollow pillar, and a rod surmounted by a small table.



Upon comparing the last two figures together, it will be seen that it is easy to adjust the two parts of the apparatus accurately to one another, so as to make the entire instrument a most effectual refrigerant.

The glass bottle *a*, of this apparatus, may be advantageously replaced by a stoneware bottle of the form commonly used in this country, for the conveyance and preservation of gallons or half gallons of spirits. I have recently had a quantity of vessels of this description prepared in Glasgow with an extra mouth, as figured in the article "Phosphoric Acid," for the insertion of a stop-cock. They are also furnished with a handle for more convenient use. A bottle of this sort, of the capacity of one imperial quart, costs 1s. A brass stop-cock, for regulating the supply of water, costs 1s. 6d.

The usefulness of this species of condensing apparatus has induced me to make some attempts to render it cheaper than it can be when constructed in agreement with the description given above. The simplest and cheapest of the modified condensers which I have yet constructed consists of a cylindrical



tube of japanned tinplate, *a b*, 10 inches long, and 1 inch in diameter, through which passes a glass tube, *c d*, half-an-inch in diameter, and sufficiently long to project 1 inch at the upper end, *c*, and 4 or 5 inches at the lower end, *d*. This glass tube is fixed

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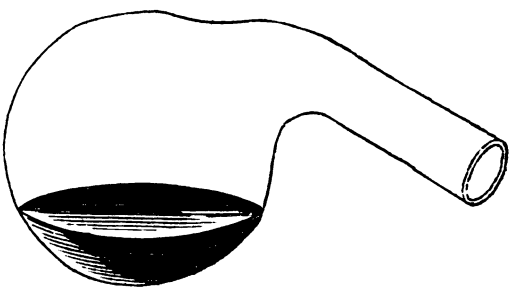
into the tin tube by two corks, *a* and *b*. The cork at the lower end is perforated in the centre. That at the upper end is bored with two holes, as shown at *e*, the larger of which is intended to fit the upper end of the glass tube, *c*. When you wish to use this apparatus, you put the point of a funnel into the small hole in the cork, *e*, and fill the large tube with cold water. You then fix the tube in a diagonal position, as represented by the cut on page 198, by adjusting the tube, *f*, soldered to the side of the large tube, and at right angles to it, upon the tube, *b*, page 42, of the tube holder, by the intermediation of a small slip of sheet Indian rubber; that is to say, you fold the piece of rubber around the tube, *b*, push the tube, *f*, over it, and then turn it round into the proper position. This apparatus can only be used in the distillation of very small quantities, because there is no contrivance for changing the condensing water, and the apparatus is useless when the condensing water becomes warm. It can, however, be used in all cases where the quantity of liquid to be distilled is not more than a cubic inch, and where the loss of a small quantity of the liquid by evaporation is of no consequence; in other words, it can be used in the preparation of small quantities of volatile acids, &c., for *testing*, where purity is required, or where particular facts have to be proven, and where so small a quantity suffices as can be condensed by the water which fills this apparatus once.

A little retort, which answers very well for use with this condenser, is represented in its full size in the following figure. It



is best when made of German glass; but green glass, or flint glass, may be used instead. The neck should fit the upper end of the glass tube of the condenser, as a stopper fits a bottle. If it is much smaller, the two should be fitted together by means of a perforated cork. All the vapour which such a retort can give over, the small condenser can convert into liquid.

When the distillation is finished, the condensing water must be shaken from the apparatus through the small hole in the cork, *e*, and the glass tube, *c d*, must be washed clean. If the

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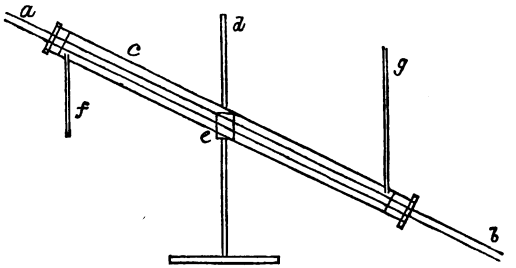
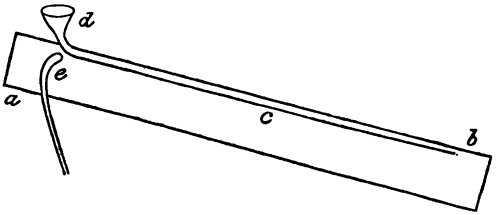
condensing water is allowed to remain in the apparatus, it speedily produces rust.

The next form of the condensing apparatus, which I have tried, is represented in the following figure:—



c is a tinplate tube, 17 inches long and 2 inches wide. *a b* is a glass tube, nearly an inch wide and 25 inches long. *f g* are two narrow tinplate tubes, communicating with the large tube, and intended respectively to supply the places of the two tubes, *c d*, in the apparatus depicted on page 198. *d* is a strong rod of wood or iron, forming part of a retort-stand, *e* is a tube of tinplate, 1 inch in diameter and 1½ inch long, soldered, in the direction shown by the figure, across the large tinplate tube, and adapted, by means of a perforated cork, to the rod, *d*. This support permits the apparatus to be raised or lowered upon the rod *d*, or turned round about it, but does not permit of alteration of the angle at which the tube rests in reference to the upright rod and the table. I give this very simple form of the large condenser, because it is one which a chemist can very easily get made in any village where there is a tinsmith. But it is a less convenient piece of apparatus for laboratory service than that which I have to describe next.



a b is a tube of tinplate 2 inches wide and 17 inches long. *c* is a narrow leaden pipe which passes along the inside of the wide tube to within an inch of each extremity, is left therein open at the lower end, but passes through the wide tube near the upper end, and terminates there in a small funnel. *e* is a piece of similar lead pipe, which enters the upper side of the wide tube

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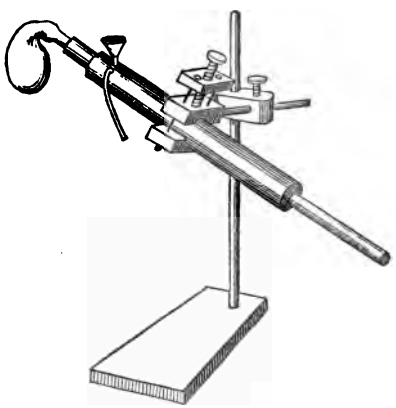
close to where the other pipe comes out, and hangs down an inch or two below the wide tube. This short tube is, like the other, open at both ends. The whole of this apparatus is japanned both inside and outside, and in this state it is sold for 4s.

When fitted for use, a glass tube, 25 inches in length, is fastened into the middle of it by means of corks fixed at *a* and *b*, and bored so as to fit the glass tube water-tight. The glass tube answers best when it is conical, being about an inch wide at the upper end, and rather less than half-an-inch at the lower end. The upper end should be bordered or provided with a rim, so as to permit the insertion of a cork without danger of fracturing it. The lower end may be melted smooth, but should not be bordered.

The tube *c*, in this apparatus is put *within* the large tube to render the apparatus more handy. The tube *e* enters the upper instead of the under side of the large tube, in order to keep the enclosed glass tube the more completely covered with cold water, especially at the upper end, where rapid condensation is of importance, as it prevents too much pressure within the retort.

Nothing answers better to hold up this apparatus than such a support as that of Sefstroem, described at page 39, a modification of which is represented below. This holder is strong and substantial. It can support any long or large vessel such as the condenser, of many pounds weight, at any height within 18 inches above the table, and in any requisite position. The price of this holder, made of white wood, is 6s. 6d.



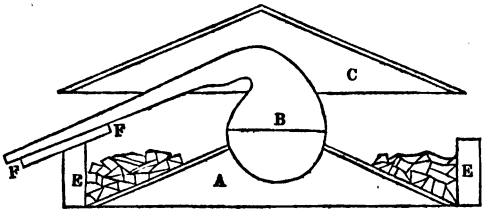
In distilling with a condenser of this description, it is necessary, in experiments upon exact quantities, to be very particular to keep the water in the tube constantly cold, which is effected by permitting a small stream of cold water to flow continually into the funnel, and placing a vessel below the pipe, *e*, to receive

the ejected warm water. But in many common operations, as in the distillation of water, it is only necessary to change the water in the condenser occasionally, for even when three-fourths of the length of the condenser feels warm on the outside, it still gives out water at the end of the tube nearly in a cold state.

The distilled product can, in general, be conveniently collected at the end of the condensing pipe, by bringing over it a long-necked flask.

I shall only add here, that I am now endeavouring to prepare both a retort (or still) and a condensing apparatus, of the same stoneware of which the lamp furnace (page 24) is composed, and which I expect will prove to be useful in the distillation of water, the purification of muriatic acid, and in many similar operations. If possible, I shall give an account of this apparatus in a subsequent part of the present volume.

DISTILLATION OF OIL OF VITRIOL.—One of the most difficult distillations to perform in a glass retort is that of oil of vitriol, for which reason I shall state, in detail, a method by which it can be effected. The causes of the difficulty experienced are, first, that this acid has a very low degree of volatility; secondly, that it contains sulphate of lead in solution, which falls to the bottom of the vessel as the distillation proceeds, and forms a mass at which the boiling goes on in fits and starts with such explosive violence as either to shatter the retort or to drive the acid over into the receiver by its mechanical power. As it is, however, of great importance to be provided with pure sulphuric acid, it is absolutely necessary to compass its distillation. The following is the method recommended by BERZELIUS.



A low broad cone of sheet iron, with its point cut off, A, is placed upon a hearth. A retort is chosen, the body of which fits the hole in the top of the cone, when about a third part of the retort is passed through the hole. Sand is put round the outer edge of the cone to hinder air from getting in below; and a row of bricks, E E, is then placed round about it. A similar cone of sheet iron, but not having the point cut off, is hung above the retort at the distance of half an inch. The retort is half filled with oil of vitriol, it is placed in the position above represented, and the neck is supported by a tile, F F. A char-

coal fire is then made upon the under cone, within the bricks E E, and is carefully sustained. After some time the acid in the upper part of the retort begins to boil, without bumping, and as the overhanging cone keeps the top of the retort hot, the volatilised acid does not condense before it reaches the neck, from the point of which the drops of distilled acid follow each other so rapidly, that if the fire is properly attended to, it is possible to distill a lb. of oil of vitriol by this process in an hour and a half. The sulphate of lead deposited during the distillation sinks to the bottom of the retort, where it is out of contact with the hottest parts of the glass, and consequently produces no explosions.

The receiver devoted to the reception of the distilled acid must be of thin glass, and the point of the retort must reach to the middle of the globe, in order that the drops of hot acid may not fall upon the glass but into the acid already contained in the receiver. These precautions are necessary to prevent the fracture of the receiver by the great heat communicated by the condensed acid.

No cold water is to be applied externally to the receiver in which distilled oil of vitriol is collected.

Another method of distilling oil of vitriol is described by BERZELIUS as follows:—The acid is diluted with water till the sulphate of lead, which is insoluble in *diluted* sulphuric acid, precipitates. The diluted acid is then concentrated by evaporation in a platinum capsule, after which it is put into a retort and distilled in the sand bath of Luhme's furnace (page 30,) being protected from the air by a jacket or dome.

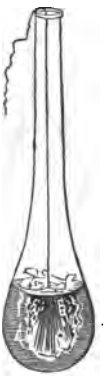
Small quantities of oil of vitriol can be distilled in small glass retorts over the lamp furnace, a long and thin glass tube, terminating in a Florence flask, being loosely attached to the neck of the retort.

In a distillation performed on the latter plan, the occurrence of explosive shocks in the retort is much hindered by putting several crooked pieces of platinum wire into the retort with the acid. The boiling then goes on quietly, and the acid produced by the distillation is perfectly pure.

This power of facilitating the distillation of sulphuric acid by the insertion of pieces of platinum wire, depends upon the general fact that rough and pointed bodies, placed in any liquid which is afterwards either warmed or freed from atmospheric pressure, have the property to originate and promote the disengagement of gas. This power is exhibited in the following experiment.

A long platinum wire is twisted into a coil at the end and is ignited, so as to produce a clean and extensive surface. A flask is half filled with water that has become saturated with atmospheric air by long exposure to it. The coil of wire is placed in the water, and the latter is slowly warmed. The atmospheric air, which is insoluble in warm water, then assumes the gaseous

state, and appears in bubbles upon the platinum wire. If now the heat is increased till the water in the flask gently boils, the bubbles of steam produced will not appear, as usual, at the bottom of the flask, but be formed round the platinum wire. This phenomenon is still more distinctly and elegantly exhibited when nitric acid (sp. gr. 1·42), or sulphuric acid, is boiled—these liquids can be kept boiling round a platinum wire for hours together, without the production of a single bubble of gas at the bottom of the liquid. As, under equal pressures, the boiling of liquids depends upon their temperature, it follows, from this experiment, that the temperature of vapours which are disengaged by platinum wire must be lower than vapours disengaged from the same liquors when heated without the wire. Consequently, the insertion of platinum wire into liquids, enables them to boil at lower temperatures. It overcomes also the attraction between the liquid and the solid material of the vessel which tends to produce that singular accumulation of intensely hot liquor in contact with the bottom of the glass, to which the explosions that occur during the boiling of sulphuric acid must be attributed.



It would be easy to extend the account of distillation far beyond the limits which I have here assigned to it; but as I shall have to enter into many details in giving instructions for the preparation of various volatile chemical compounds, I do not think it necessary to enter now into those minutiæ, inasmuch as it would produce needless and not very entertaining repetitions.

MANAGEMENT OF GASES.

For performing experiments with gases, many articles of apparatus, not hitherto described, are necessary. These consist, partly of vessels for containing the materials which afford the gases, and partly of vessels adapted to contain the gases and submit them to experiments. Some gases are procurable by the mere mixture of the substances, which, upon combining, evolve them; but others cannot be obtained without submitting the materials to heat. For these different modes of proceeding, it is requisite to employ a diversity of vessels.

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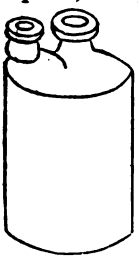
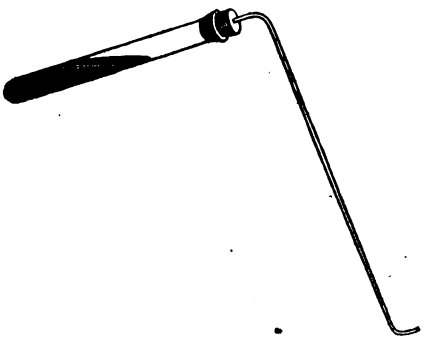
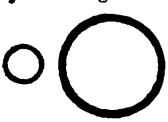
For the gases which are prepared with the aid of heat, you may employ a retort, a Florence flask, or any other glass vessel, the bottom of which is thin enough to bear the application of heat without cracking. The same vessels may be employed for the preparation of such gases as do not require the aid of heat; but in general the latter can be more readily prepared in vessels which stand steadily upon the table without support. Such a vessel is the *Woulfe's bottle*, exhibited by the annexed figure. It is simply a broad short glass bottle, furnished with two necks. When very small quantities of gases are to be prepared, the operations may take place in small bottles of the description figured in page 11, or in little matrasses and retorts constructed of glass tubes (pages 10, 193.) Oxygen gas is sometimes prepared in an iron retort, and hydrofluoric acid gas in a platinum or leaden retort; but glass is the material which is generally made use of for retorts.



A very small quantity of a gas can also be prepared in such a tube retort as is figured below. This consists of a straight closed tube, the mouth of which is stopped by a cork, through which is passed a tube for conducting gas.



The wide tube may be 4 inches long, and of the width shown by the larger of the following figures. The conducting tube may be as wide as the smaller of the two figures. The wide tube should be made of hard German glass. The narrow tube may be of flint glass. This apparatus is very useful in the preparation of small quantities of pure oxygen gas.



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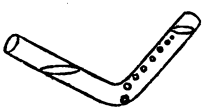
When you need to ascertain the nature of a gas given out in a particular operation, a tube like the following may be employed. This tube should bulge out a little at the elbow, and the part which bulges out should be below the sealed end of the tube. If you put some muriatic acid into such a tube, then hold it in the position shown by the figure, and drop a bit of marble into it, the marble will descend to the bulge, where it will be decomposed by the muriatic acid, and a quantity of carbonic acid gas will be produced, all of which will ascend in bubbles to the sealed end of the tube, and none will escape. In this case, a single tube acts the double part of a retort and a receiver. This apparatus is sometimes more useful, when the sealed end is turned over a little, made into a mouth, and provided with a stopper.



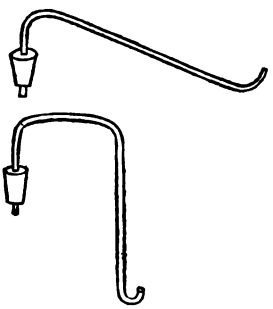
Previous to the examination of a gas collected in this manner, it is often necessary to replace the acid in the tube by water. To do this, you close the open end of the tube with your thumb, plunge it into water, and then remove your thumb and elevate the closed end of the tube, so as to allow the denser acid to run down, and the water to ascend and supply its place.

It is in most cases *essential* to the form of a bottle in which gas is to be made, that its mouth has a *spreading lip*, so that a cork can be readily fixed into it air tight. It is equally essential that the neck of the bottle be either quite cylindrical, or else wider just at the mouth than it is a little way within it; for if, as in many cases, the neck of the bottle gradually gets narrower towards the mouth, so that the diameter there is less than at any other part of the neck, it is nearly impossible to adapt a cork to it air tight, and consequently it is impossible to convey the gas thence to the place where it is required. There is no difficulty in procuring a bottle with a good mouth when the bottom of the bottle is allowed to be thick; but it is impossible to procure thin flint glass flasks with turned lips, because they cannot be made with turned lips, unless we submit to have a thick lump of glass left by the *punty* at the bottom of the flask, exactly in the place where it is certain to cause the glass to split the first time it is put over the lamp. This, however, is not the case with bottles made of crown glass, which are prohibited to be made in this country, but which can be procured from Germany, perfectly thin at the bottom, to admit of the application of heat, and yet with well formed mouths for the reception of corks.

Method of Proceeding to make a Gas.

Put into the gas bottle the materials whose re-action is to produce the desired gas. Break the solid part into small pieces to facilitate chemical action; put in the powder through a warm funnel, and pour in the liquid through a funnel, to avoid soiling

the neck of the bottle. If your bottle has two necks, one of them should be provided with a ground glass stopper, or a cork that fits close. The neck through which the gas is to escape, should be closed by a cork provided with a glass gas tube, bent more or less, according to the distance and shape of the vessels into which the gas is to be conveyed. The sort of tubes necessary to be employed in these experiments, is of soft flint glass, because that kind is most easily bent into the desired form. The size of the tube must depend upon the quantity of gas that is to be conveyed; a wider tube being necessary where a large mass of materials is set to work at once, than where only a small quantity is employed. According to circumstances tubes of the following sizes may be employed:—

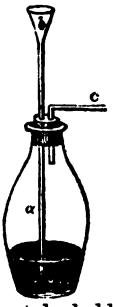


The point of a tube which is to deliver gas, should always be slightly turned up. It facilitates the discharge of the gas.

When the conducting tube is fixed into the bottle, apply your mouth to the open end of the tube, and *suck* strongly: you will thus ascertain whether or not the joinings of the apparatus are completely air tight, and if not, they must be made so. You will, of course, make this trial when the bottle is empty, and not while a gas is being generated within it. If the joinings are not air tight, they may sometimes be rendered so by applying a small quantity of a cement; but it is better to fit new and sound corks on the tubes. The corks should be first perforated by the method described in the section on "Cork Boring."

The materials put into a bottle to produce a gas, must never exceed in bulk the third or fourth part of the capacity of the bottle, otherwise they are apt to boil over when the action comes to be powerful, and the disengagement of gas rapid. When the materials consist of a liquid and a fine powder, the liquid should be put into the vessel first, and the powder afterwards, and the two should be carefully mixed by shaking the vessel. You must take care not to respire an atmosphere contaminated by deleterious gases. Sulphuretted hydrogen gas is a particularly powerful poison, and it is fortunate that its noisome odour gives timely notice of its presence. Chlorine gas is exceedingly difficult to breathe, but it is not so injurious as the preceding. Arseniuretted hydrogen gas is very deadly; a celebrated German chemist was killed by smelling it. Carbonic acid gas occasions suffocation if mixed with the air in large proportions. Experiments with deleterious

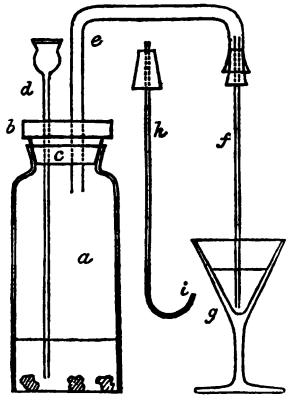
gases ought not to be made in a close apartment, but either under a large chimney or in the open air. The first portion of gas, of whatever kind it may be, evolved from the vessel in which it is formed, is always contaminated with the common air with which the vessel was filled at the beginning of the operation. A quantity of the first air received, equal in bulk to twice the capacity of the vessel, must, therefore, in order to avoid accidents and failures, be thrown away. The measuring of this quantity is effected by collecting it in glass jars over water, by a method to be described immediately.



It is sometimes necessary, during a distillation, to give a fresh supply of acid to the mixture in the gas bottle. To be enabled to do this without interrupting the process, it is proper to provide the neck of the bottle with a cork containing two holes instead of one. You fix into one of these holes the tube which is to convey the gas, and into the other a tube with a small funnel *b*, at its upper end, and with a neck *a*, so long that it dips into the liquid contained in the gas bottle. It is by means of this funnel and tube, that you are to introduce the acid at all times when it is required.

When the gas bottle is to be exposed to heat, it must be held over the lamp by one of the supports, or retort stands, already described.

Clark's Gas Bottle.—The following apparatus is extremely useful in preparing sulphuretted hydrogen gas, to be used in testing, or in preparing hydrogen gas, carbonic acid gas, or any of those gases which do not require the application of heat to the materials which yield them. I shall describe this bottle and the method of preparing sulphuretted hydrogen gas with it, as an example of its use. *a* is a glass bottle six inches high and two inches wide; *c* a cork adjusted to the neck of it; *b* a round piece of wood cemented to the cork; *d* a glass funnel with a long and narrow neck, passing through and cemented to the wood and cork; *e* is a bent tube nearly half an inch wide, terminating in a spreading mouth adapted to receive a cork; *f* is a narrow glass tube open at both ends and fixed into a cork that suits



the opening of the wide tube. All the parts of the apparatus, therefore, hang together by the wooden block *b*.

Lumps of sulphuret of iron are put into the bottle *a*, and water is added till it rises about an inch and a half in the bottle. The cork *c* with its appurtenances, is then fixed in its place; sulphuric acid is poured little by little down the funnel *d*; upon which sulphuretted hydrogen gas is soon produced and expelled from the mouth of the tube *f*. As the general purpose of preparing this gas is to pass it into a liquid to ascertain what coloured precipitate it gives, the size and height of the bottle is adapted to this object. The liquid to be acted upon is put into a test glass as represented in the figure, and as described at page 53. The tube *f* is made of such a length as to pass nearly to the bottom of the test glass. The liquid in the bottle *a* rises in the tube *d* as high as is equal to the dip of the tube *f* into the liquid in the glass *g*. But no inconvenience arises from this, and if the proportions of the parts of this apparatus are properly observed, there is never any violent effervescence, or absorption, or other accident produced, to interrupt the experiment in progress.

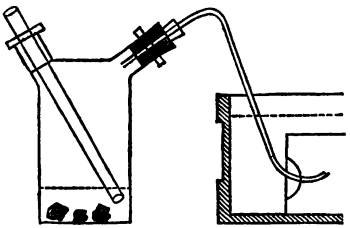
When the operation is over, and no more gas is required for a time, the cork *c* is removed from the bottle *a*; the liquid is thrown out, but not the solid sulphuret of iron; the latter is rinced with clean water which is thrown away, and then the bottle is filled up with clean water, the cork is put in its place, and the apparatus is set aside till the gas is again in request.

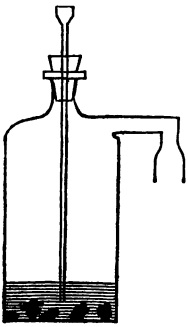
When the gas produced in such a bottle is to be collected as gas, in cylinders, then the tube *f* is withdrawn and is replaced by the tube *h*, by means of which, properly bent, the gas can be conveyed in any required direction.

In passing the tube *h* into a water trough, heed must be taken as to the depth of the dip into the water; for, as I have said, according to the dip of this pipe below the surface of any liquor, is the height to which the water in the bottle *a* rises in the funnel *d*. If you incautiously force the tube *h* very far below the surface of the water in a trough, the consequence may be the expulsion of the whole of the liquor from the bottle *a*, through the funnel *b*. In all cases where it is necessary to pass the tube *h* far into a mass of liquid, the funnel tube *d* must be lengthened as shown in the upper figure on page 209. The notice here given applies to all bottles in which there is, as in this bottle, a combination of two open tubes.

The next figure exhibits an imitation of the above apparatus made in stoneware. It consists of a Woulfe's bottle with two necks fixed on diagonally. The funnel is here replaced by a tube of stoneware, the lower end of which nearly touches the bottom of the bottle. The other neck of the bottle is about an inch wide, and is fitted with a large perforated cork. The materials for producing a gas are introduced by this neck, the cork being removed for that purpose, and the vessel is emptied at this neck. When the gas issues through the hole in the cork,

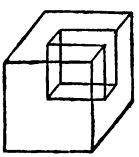
it is conveyed thence in any direction it may be wanted, by a small *delivering* tube adjusted by a small cork to the large cork. As represented in the cut, it is delivering gas into a water trough; but with a tube of a different shape it can be used in testing with sulphuretted hydrogen gas, in the same manner as Clark's gas bottle. The opacity of the bottle renders it less convenient than the glass bottle, but it is much cheaper. The price of Dr Clark's gas bottle is 3s. The price of this stone bottle is 1s. 6d. or when not fitted with tubes, 1s. The annexed figure exhibits another cheap stoneware bottle adapted for the same purposes as the above. It appears needless to give any particular description of it, as it is used precisely like Clark's bottle. Both the funnel and the delivering tube of this apparatus are of stoneware. The funnel is passed through a cork.—I have several other forms of stoneware flasks in course of manufacture, that is to say, I have flasks of different sizes and shapes, part with flat and part with thin round bottoms,—some of them making, and some under trial, with a view to ascertain whether generally useful forms of vessel for gas distillations superior to those of glass now in use, and much cheaper, cannot be made of stoneware. These trials are however not so far advanced as to enable me to give any exact descriptions of them at this moment; but I hope and expect to succeed in preparing cheap stone flasks adapted for use in many cases of gaseous distillation.



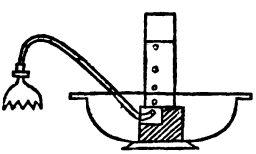


Collecting of Gases.—When glass jars, or any other vessels, open only at one end, are plunged under water, and inverted after they are filled, they will remain full, notwithstanding their being raised out of the water, provided their mouths be kept immersed; for, in this case, the water in the jar is sustained by the pressure of the atmosphere, in the same manner as mercury in a barometer. It may without difficulty be imagined, that if common air, or any other fluid resembling common air in lightness and elasticity, be suffered to enter these vessels, it will rise to the upper part, and the water will subside. If a bottle, or cup, or any other vessel, in that state which is usually called empty, though in reality full—of *air*, be plunged into the water

with its mouth downwards, scarcely any water will enter, because its entrance is opposed by the elasticity of the included air; but if, while the vessel is immersed, its mouth be turned upwards, the air will rise in bubbles to the surface of the water, leaving the water to occupy its place in the vessel. Suppose this operation to be performed under one of the jars which are filled with water, the air will ascend as before; but, instead of escaping, it will be detained in the upper part of the jar. In this manner, therefore, we see, that air may be emptied out of one vessel into another by an inverted pouring. Just in this manner are gases collected in vessels placed in what is termed a pneumatic trough: the jars which are to receive certain elastic fluids, are filled with water, and placed, mouth downward, upon a shelf, and the necks of retorts, and ends of tubes, from which gases are evolved, are directed below holes made in the shelf under the jars; then the gases, as they issue forth, rise in bubbles through the water, enter the jars, driving thence the water, and occupying its place. When, therefore, the jars are thus emptied of water, they are filled with gas.



The pneumatic trough is simply a wooden tub, or vessel of tin-plate, filled to within two inches of its top with water It should be provided with a shelf, placed an inch below the surface of the water, or with a wooden block, cut into the form shown by the figure, and plugged with lead to make it sink in water. When you wish to fill a jar with gas, you place it full of water, in an inverted position, over the hole cut in the block, and you direct the point of the tube whence the gas is to issue into this same hole. The water in the tub must rise about an inch above the top of the block. The size or form of the trough is quite immaterial. A wash-hand basin answers the purpose very well. The annexed figure exhibits the mode of putting together a pneumatic apparatus, such as has been here described.



I shall describe a different sort of shelf and pneumatic trough presently.

Receivers for Gases.—Any kind of glass vessel can be employed as a *receiver* for gases; in the last figure, a plain cylinder is represented; but particular experiments require vessels of a particular size and form. This will be adverted to when necessary. Lecturers on chemistry generally employ a metallic gas holder to contain large quantities of oxygen or hydrogen gas. If at any time a large quantity of oxygen gas is prepared, when no gas holder is at hand, it may be put into green glass wine

bottles, and corked up. Each bottle should be placed aside, bottom upwards, with the mouth plunged into a little pot of water. The gas will not escape.

When a bottle has been filled with gas in the manner described above, it may be corked under water, and then removed from the trough. If a jar with a wide mouth has been filled, you must fill a tea saucer, a soup plate, or other shallow vessel, with water, and slide the filled jar from the block into the soup plate, the small quantity of water contained in which will prevent the escape of the gas from the jar.

Little trays of stone ware are prepared for this purpose in Glasgow. Three sizes are to be had. The price of each of which is three halfpence, or the set for 4½d.

A set of four small cylindrical glass jars adapted for experiments upon gases have been described at page 63. The price of the set is 2s. Another jar useful in such experiments as the burning of phosphorus in oxygen gas, open at the bottom and with a wide neck at the top, should also be provided. The price of such a jar of five inches in height is 1s.

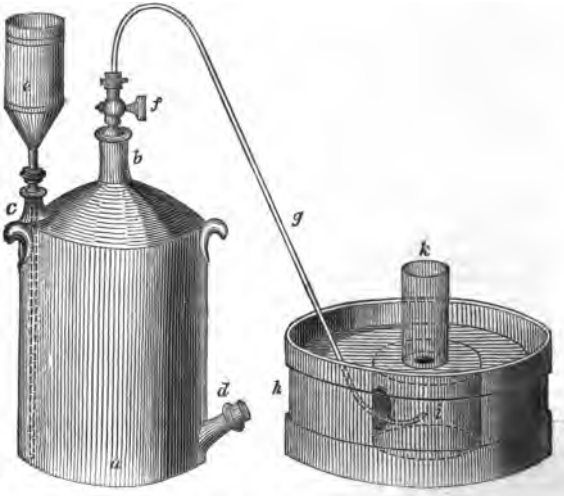
When you want to transfer gas from a wide mouthed into a narrow mouthed vessel, you must hold a funnel in the mouth of the latter. All transfers of gas must be effected under water, and, as it has been expressed above, by an inverted pouring. As water emptied in air descends, so air emptied in water ascends. This is the principle upon which depends the decantation of gases.

Filling of Bladders with Gases.—As it is frequently necessary to fill bladders with gases, I shall describe the method of doing it. The following figure represents an apparatus employed for this purpose. *a* is a glass receiver, supposed to contain gas; it is open at the bottom, and provided with a brass cap and stop-cock at the top. A vessel six inches in diameter and eight inches high, is sufficiently large for a student's experiments. *d* is a bladder, in the mouth of which a stop-cock is fastened by means of a ferrule. *f* is the side of a pneumatic trough; *h* is the shelf, *g* the level of the water, *e* and *b* are the stop-cocks by which the bladder and receiver are connected.

Moisten the bladder with water to render it flexible, squeeze it close to expel the common air from it, then shut the stop cock *e*, and screw it to the stop-cock *b*, on the top of the receiver, which is supposed to be placed on the shelf in the trough. Next, open both the stop-cocks, hold the apparatus in the manner shown by the figure, gently slide the receiver off the shelf, and press it down into the water; the gas will soon enter and fill the bladder, being forced through the opening by the upward pressure of the water. The stop-cocks are then to be closed, the receiver replaced on the shelf, and the two vessels disunited. Previously to undertaking experiments on gases, the young student should accustom himself to the dexterous management of gases, by performing the processes of decantation, filling of bladders, &c., with common air.

Stoneware Gas Holder.

In all cases where a *series* of experiments with the same gas are to be performed, as when a teacher has to demonstrate the properties of oxygen gas or hydrogen gas, it is convenient to begin by preparing a quantity of gas sufficient for the performance of the whole series, and then to proceed uninterruptedly with the experiments. I shall here describe a cheap and handy apparatus for storing gas for this purpose.



a is a stoneware bottle of about a gallon and a half capacity, or about 10 inches in diameter and 13 inches in height. It is furnished with three necks, *b*, *c*, *d*. The neck *d* is fitted with a

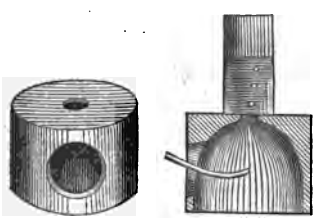
cork. The neck *b* is provided with a stop-cock, *f*, which is cemented into it. The neck *c* is cemented round the upper end of a metal tube, which descends very nearly to the bottom of the bottle. There is a coupling screw soldered to the top of this tube, to which the large japanned iron funnel *e* can be connected when necessary. *g* is a flexible metallic pipe two feet in length, connected to *f* by a screw.

To fill this Gas Holder with Water.—Close the neck *d* with its cork. Open the stop-cock *f*, and pour water into the funnel *e*, till it runs out at *f*, (the tube *g* being supposed away).

To fill the Gas Holder with Gas.—Close the stop-cock *f*. Take out the cork at *d*, and pass into the neck *d*, the delivering tube which comes from the bottle in which the gas is being prepared. The gas will then rise in the vessel *a*, and an equivalent bulk of water will flow out at *d*. Of course, the gas holder must be placed during this process over a tub sufficiently large to receive the water that runs out. The quantity of the water thus collected, shows the quantity of gas that has entered the gas holder. When water ceases to run out of the mouth *d*, notwithstanding the continuance of the delivery of the gas into it, the gas holder is filled with gas.

Stone Pneumatic Trough.—Before noticing the method of expelling the gas from this gas holder, it is proper to describe a new form of pneumatic trough which is to be used with it.

h, in the last figure, is this trough. It is a pan of stoneware 11 inches in diameter, and 5 inches deep. The shelf for supporting the jars in this trough, and for gathering the gas beneath the jars, is the most peculiar part of it. This is represented by letter *i* in the above figure, and under different points of view by the two figures below.



This shelf is an inverted stone pan, cylindrical on the outside, but shaped like a bee hive within. It is 4 inches broad, and $3\frac{1}{2}$ inches high. On the side it has a round opening of 2 inches diameter to admit the entrance of retort necks and delivering tubes, and in the top it has an opening of half an inch in diameter, to permit the passage of gas from the bee-hive below, into the jars placed upon it. When this shelf is put into the trough, but close to one side of it, there is room left for working with pretty large cylinders. The gas is collected very effectually from any

sort of delivering pipe, and with great readiness, and without any loss, it is conveyed even into narrow mouthed flasks, placed in the position indicated by figure *k* in the cut on page 214.

To pass Gas from the Gas Holder into a Jar.—The flexible metal pipe is first placed in the position shown by the figure on page 214, and adjusted to the bee-hive and trough, which is filled with water to within half an inch of the top. The jar is filled with water, inverted, and placed upon the bee-hive in the trough. The funnel *e* is filled with water. You have then only to open the stop cock *f*, when the gas immediately passes into the jar *k*. When the jar is as full as you wish it to be, you close the stop cock *f*.

In experimenting with this apparatus it is advisable always to use cylinders of a smaller capacity than the funnel *e*, in order that one filling of the funnel may be sufficient for each experiment.

To fill a Bladder or a Balloon with Gas from the Gas Holder.—Attach the compressed bladder to the end of the pipe *g*, pour water into the funnel *e*, and open the stop cock *f*.

In the same manner can the gas be forced out upon any given object. Thus, oxygen gas can be forced out upon burning charcoal to cause the fusion and combustion of metals, &c.

The price of this gas apparatus is as follows:—

Gas holder with funnel and flexible pipe, . .	8s. 6d.
Pneumatic trough and bee-hive shelf, . . .	2s. 0d.
Set of 4 cylindrical glass jars, ...	2s. 0d.
Open glass jar for deflagration, ...	1s. 0d.
Iron spoon for deflagration, ...	0s. 6d.
Set of 3 stone trays for the jars, ...	0s. 4½d.
	14s. 4½d.

It is scarcely necessary to add that this is the cheapest gas apparatus that has ever been produced.

JAPANNED WATER TROUGH.—The figure on p. 217, represents a very light and convenient pneumatic trough made of japanned tinplate. It is adapted for experimenting with jars of 60 cubical inches and under. The trough is 10 inches long, 6½ inches wide, and 4 inches deep. The clear water way *a* measures 10 inches by 4 inches. The shelf *b* is ½ inch wide. The shelf *c* is 1½ inch wide. These shelves are made by bending a tin plate into the form shown by the end of the trough *e*. At the corner of the trough *f* there is a small tube which carries off the water that descends from jars when filling with gas, as soon as the level of the water in the trough arrives within half an inch of the edge. A separate tray, of the size of the cavity *a*, is provided to catch this water, and is placed for that purpose under the side *f* of the trough. The shelf *d* is moveable and slides between the shelves *b* and *c*, the whole length of the trough. A small box is made below the shelf *d*, to catch the gas from the delivering pipe, which is brought

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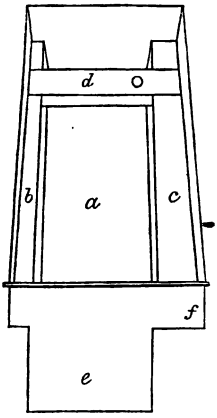
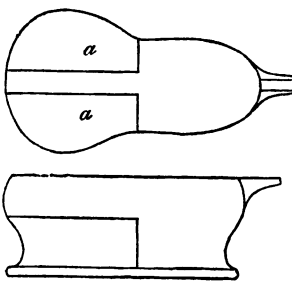


below it, and a small hole in the upper part of the box permits the gas to pass into jars placed above it. In operating with this trough, you place it crosswise on the table before you, with the end *e* to your right hand. The bottle in which you are preparing the gas that is to be collected, must be placed upon your left hand, with the delivering tube dipping into the water trough just low enough to go under the box soldered below the shelf *d*. You then fill the glass jar with water, invert it, and place it upon the shelf *d*, and adjust the latter over the mouth of the delivering tube. When the jar is full, you remove it upon a small tray, and place it, if you wish to set the small tray at liberty, in the long tray which serves to catch the overflowing water from the trough. By this means the long tray is rendered equivalent to extra shelf room in the trough. The price of this trough, 3 pieces, japanned, is 4s.

Mercury Trough.

Many kinds of gas are condensed by water, and cannot be collected in jars inverted over water in the manner described above. Such gases can only be confined by mercury, for which reason it is necessary for the chemist who desires to operate upon gases of that kind, to be provided with a trough containing a quantity of mercury. The expensiveness of that metal makes it desirable to have the trough so formed as to take as little mercury to fill it as is consistent with the power of performing the necessary operations. I shall describe two troughs of this description.

Berlin Porcelain Trough for Mercury.—The figures represent a surface view and a section of this apparatus. It is 7 inches long, 4 inches wide, and 3 inches deep. *a a* are two shelves $1\frac{1}{4}$ inch high. The price of it in Glasgow is 10s. This trough is employed by Liebig as a part of his apparatus for Organic Analysis, and it is used by several of the German chemists in the performance of class experiments. It requires about 10lb. of mercury to fill it properly.



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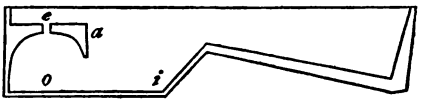
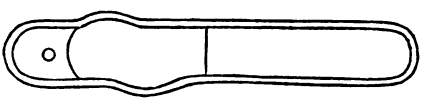
Stoneware Mercury Trough.—I have lately made some endeavours to construct a stoneware trough, that should be lower



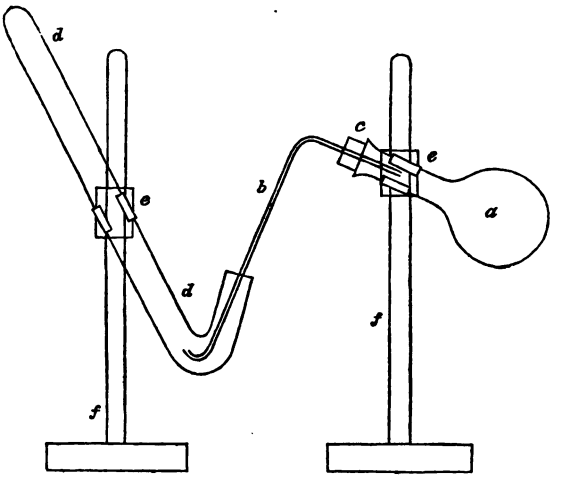
in price than the foregoing, that should require a smaller quantity of mercury to fill it, and yet be large enough to permit of the performance of very satisfactory experiments. The result is depicted in the above cut. It requires 4lbs. of mercury to fill it. It takes in a tube 6 inches long and 1 inch wide, and allows it to be safely inverted when full. At *a* there is a shelf upon which the tube rests to be filled with gas, which can be passed in by a delivering pipe under the bee-hive *o*, whence it passes through a hole at *e*. At *o*, *i*, there is a cavity which admits a glass tube 2 inches by ½ inch, and gives the operator the power of passing caustic potash or other re-agent into the cylinder placed above the hole *e*. Between *a* and *i* are two recesses which afford passage for a thumb and finger, to manage the small tube depressed for this purpose into the cavity *o i*. The following figure gives a surface view of this trough, which



bears some resemblance to an Egyptian mummy case, while the side view of the apparatus is not very unlike a shoe. The price of it is 1s. 6d. When in use, it requires to be placed in a dish or tray to catch the mercury which may run over the edge during the operations. The stone water trough, page 214, answers this purpose very well.

Cooper's Mercurial Receiver.

The following cut exhibits a method of collecting gas over mercury in a tube, and therefore of dispensing with the use of a trough. *e f*, *e f*, are two tube holders, such as are described at page 41. *a* is a flask in which a gas is supposed to be generating; *b* a narrow tube for delivering the gas; *c* a cork by which the delivering tube is adapted to the flask. *d d* is Cooper's bent gas receiver. The length of it is 12 inches to the elbow; the neck is 2 inches; the width, ⅝ inch. It is closed at the top, but open at the bottom. At the beginning of the operation, this receiver is filled with mercury, and a basin is placed below the mouth of it to catch the mercury which may be displaced by the gas. The operation is stopped when the tube is filled with gas nearly to the bend. The following account of



the method of examining a gas collected in such a tube receiver, I take the liberty of extracting from Dr FARADAY'S "*Chemical Manipulation.*"

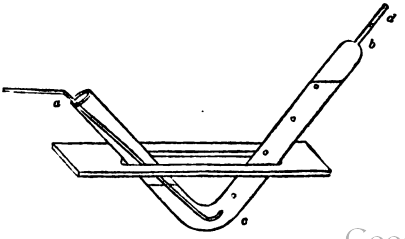
"The gas thus collected may be examined as to a great number of its characters without the help of any other tube, or of any transference but what may be obtained by moving it from one part of the tube to another. For instance, the finger may be placed on the aperture, in contact with the metal, so as to exclude all air, and close the mouth of the tube; then inclining the tube, a bubble of the gas may be made to pass round the bend towards the finger; this done, upon restoring the tube towards an upright position, the larger portion of gas will still be in the upright part, but a quantity varying from a quarter to three-quarters of an inch in extent, according to the will of the operator, may be confined between the mercury and the finger, and quite unconnected with the larger portion. This quantity may be tried as to inflammability by bringing a lighted taper near the aperture, and immersing it in the gas the moment the finger is removed. Suppose this trial made and that knowledge acquired, then by pouring in mercury, so as to fill the small space now unoccupied, re-applying the finger and re-inclining the tube, another portion of the gas is brought into a situation similar to the former; this may be examined as to smell, and its odorous or inodorous nature ascertained. Again filling the space with mercury, and repeating the operations as before, a third portion of gas is brought to the mouth of the tube, and this may be examined as to whether it is heavier or lighter than the atmosphere, if from the two previous trials it appeared to differ in quality

from common air; thus, if, after leaving the mouth open a short time, the gas, or a part of it still remains in the tube, it must be heavier than air, whereas if all signs of it have disappeared, it is a proof of its lightness as compared with that standard. In a similar manner trial may be made of the solubility of the gas in water, by filling up the space left by the last experiment with water instead of mercury, or at least in part by water, and then bringing a bubble of gas to that part as before; if it instantly disappear, it indicates considerable solubility, if it does not at all diminish, it shows comparative insolubility. If a solution be actually formed, then upon removing the finger it may be examined as to its acid or alkaline nature, or other properties.

"In these and similar experiments great care should be taken that no water pass beyond the bend into the tube, for which reason but little water should be put in at once; there should be sufficient mercury between it and the angle to replace the bubble of gas which is to be brought to the mouth, and the inclination of the tube should be carefully attended to, that no water inadvertently pass backward into the higher part. When the trial of solubility is over, the water should be taken from the mouth of the tube, first by a folded piece of bibulous paper, and afterwards with tow upon a wire. Trials may be made with lime water or alkaline solutions, their action upon a part or the whole of the gas being in this way easily observed.

"Thus the gas may be divided into many successive portions, and submitted to numerous examinations; and should it so happen that a part is absorbed by water and a gas left which could not be properly examined whilst in a state of mixture, then, after having made the proper experiments upon the mixture, a little water may be let into the body of the receiver, and shaken with it, to absorb the soluble gas, and the finger being removed from the aperture, either under mercury or water, those fluids will enter and supply the place of the absorbed substance. The insoluble and purified remainder may now be examined in successive portions in the manner just described."

The following apparatus pretty nearly resembles Cooper's Tube in its nature. It is useful in cases where the relation of a gas



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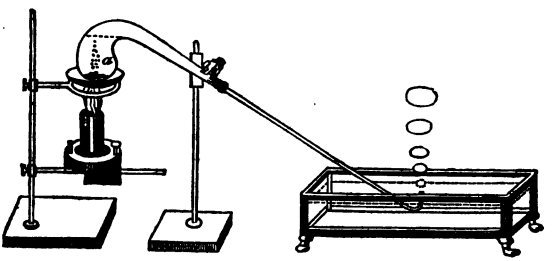
to a particular liquid is to undergo examination. For this purpose, the tube is three parts filled with the liquid in question, so as to shut out atmospheric air from the branch *c b*. It is then fixed in a slit board or in a tube holder, in the position here exhibited, and the gas delivering tube, *a c*, is then inserted, and the gas passed up into the liquid between *c* and *b*. Its absorbability is thus readily ascertained, and the resulting solution can be readily examined. If any gas remains unabsorbed, and is to be further examined, the tube must be first filled with water, and the fine point *d* be then plunged into water, and broken off below a vessel placed to receive the liberated gas; or, after closing the tube by the thumb, the gas may be transferred to the branch *a c*, and be let out at the mouth *c*.

This apparatus can also be usefully employed as a receiver in the distillation of nitrous acid and other condensable gases. The retort, containing the materials for producing the gas, is adjusted by means of a perforated cork or a caoutchouc connector to the mouth *a* of the receiver, which is to be supported by a tube holder. A bulb retort, such as is represented on page 200, answers this purpose best. The bend of the receiver is then to be dipped into a mixture of ice and water, or to be loosely wrapped about with tow, and kept constantly moistened with ice cold water. Heat being applied to the retort, nitrous acid passes into the receiver and is condensed at the bend *c*.

Glass Pneumatic Trough.

The trough exhibited in the following cut is adapted for the Lecture Table. It is constructed of plate glass, bound together by a frame of polished brass. The operation exhibited in the



cut is the preparation of spontaneously combustible phosphuretted hydrogen gas. The distillation is effected in a retort, which is supported upon a shallow sand bath; a method of spreading the heat of a lamp which is useful in many cases, and frequently saves a glass vessel from destruction. The neck of the retort is gripped by a Gay Lussac's retort holder (page 38.)

Here is another representation of the glass pneumatic trough, with the addition of its plate glass shelf for the support of jars,

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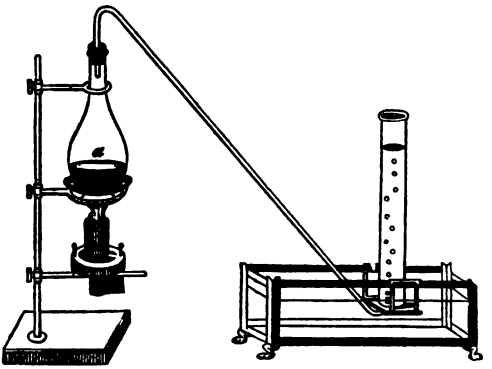
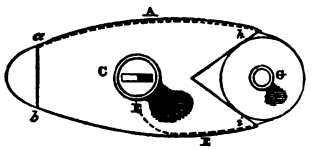
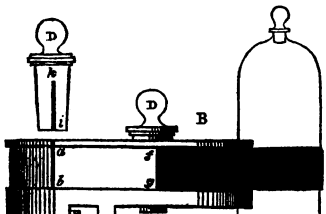
the shelf itself being supported by a frame of brass which fits the edges of the trough. The operation exhibited in this print is the preparation of chlorine gas. I recommend your observance of the method of adjusting the parts of the apparatus, and the mode of securing the flask above the lamp.



Gahn's Cylinder Holder.

The following is Berzelius's account of Gahn's holder for flasks, cylinders, and bell jars, over the pneumatic trough. The first of the following figures, A, represents the principal portion of this apparatus, as when seen from above. The second figure, B, exhibits the same in profile. The instrument is made of wood. A slit three quarters of an inch deep is sawed in the block at *a b*, and in this slit a strong silken band or ribbon of the same width is placed, the end of it being secured by a thick edge or seam down the side *b*. The end of this band is then carried round from *a*, in the direction A *h* G *i* E, and through the slit *f g*, (fig. B.) into the conical hole C, where it is fastened in another slit, *k i*, cut in the conical peg D. The band is wound up round this conical peg and fixed,





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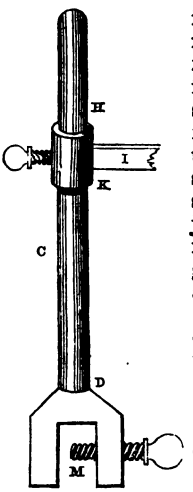
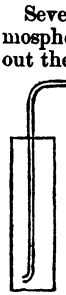
when necessary, by pressing the peg into the conical hole. Conversely, the band can be loosened by slackening the conical peg. Consequently, a glass cylinder, as G, placed in the triangular opening *h i*, can be held fast or let loose at pleasure. The remaining part of this apparatus consists of the frame, I H M, which can be screwed to the side of a pneumatic trough by the screw at M. The upright rod, H D, is cylindrical, the arm I is square, and adapted to the square hole F shown in figure B. The two screws, N and K, permit of all requisite adjustments of position, and when the instrument is sufficiently strong, it holds the glass jar with perfect steadiness. The operator who has once experienced the great convenience afforded by this instrument in experimenting upon gases, says Berzelius, will be extremely unwilling to dispense with its services.



The price in Glasgow of this apparatus, of German make, is 8s. I shall describe a cheap modification of it, under the head of "Universal Support."

Collecting of Gases by Displacement.

Several gases, which are either lighter or heavier than atmospheric air, may be collected in tolerable purity, and without the aid of any trough, as follows:—



To Collect Heavy Gases.—Let *a* represent a clean dry glass cylinder, and *b* the tube which brings the gas to be collected from the vessel in which it is produced. As the heavy gas issues from the tube, it settles at the bottom of the cylinder, and forces the lighter atmospheric air to ascend and flow out of the top of the vessel. Thus the heavy gas gradually displaces the air, and soon fills the cylinder. Chlorine, muriatic acid, sulphureous acid, and carbonic acid gases can all be collected in this manner. You readily ascertain when the vessel is full of chlorine gas, in consequence of the yellow colour of that gas. Muriatic acid gas flows over and produces fumes in the air. You test the fulness of vessels containing carbonic acid and sulphureous acid gas, by putting a lighted match near the opening. If the light goes out, the gases have risen to the top. You must allow a little gas to flow over, to ensure the expulsion of all the common air from the cylinder. It is best to use a very small receiver, and to conduct the operation slowly, and when the receiver is full, to remove it from the delivering tube gradually.

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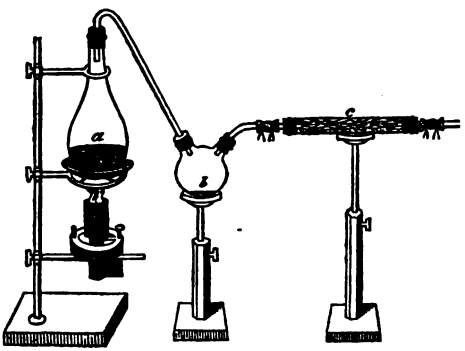
To Collect Light Gases.—Gases that are lighter than atmospheric air, such, for example, as ammonia, can be collected by a process which is the reverse of the preceding, and which is pictured in the margin. A tube passes *upwards* to the top of a receiver, the light gas escapes from the tube, settles at the top of the receiver, and depresses and drives away the whole of the atmospheric air. By holding a slip of wet turmeric paper to the mouth of the jar, you easily learn when it is full of ammonia, because turmeric is coloured red by ammonia.

When gases are thus collected, they can be secured in bottles by the insertion of greased glass stoppers, or in cylinders by the application of greased glass plates. But gases thus collected ought to be immediately submitted to experiment.

Drying of Gases.

It is often necessary to prepare a current of chlorine gas or hydrogen gas, freed from watery vapour. This is the apparatus employed for the purpose :—



The gas is prepared in the flask *a*, whence it passes into the two necked receiver, or intermediate vessel *b*. A good deal of the moisture is deposited there, whence the gas, pursuing its course, passes into the tube *c*, which is filled with lumps of chloride of calcium, recently fused to deprive it of water. This substance eagerly abstracts the vapour from the gas, and the latter issues forth at the other end of the tube perfectly dry.

The tube *c* employed to contain the chloride of calcium, best answers the purpose when it is about 10 inches long and two-thirds of an inch wide, and is closed at each end by a cork with a short piece of gas delivering tube passed through it, as represented in the figure.

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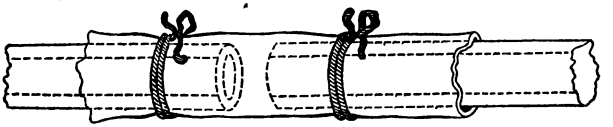
The ends of this drying tube are not fixed immoveably to the other parts of the apparatus, but are connected to it by means of short tubes of indian rubber of the following size, and tied on in the following manner :—



I shall describe the method of making these tubes in another section, making here only the remark that they are extremely useful in connecting together the tubes of a distilling apparatus, because they easily make air tight junctions, while they permit a considerable degree of moveability among the connected vessels.

Measurement of Gases.

Gases are measured by being introduced, either over water or mercury, into jars or tubes graduated into parts of equal capacity. The accurate measurement of gases cannot be effected without taking a variety of precautions.

Weighing of Gases.

To ascertain the specific gravity of gases, it is necessary to have good apparatus and great skill in experimenting. A glass globe, provided with a stop cock, is weighed. It is then exhausted of air by an air pump, and weighed empty. It is afterwards filled with gas, and again weighed. The weight of the common air, compared with the weight of the gas, shows the specific gravity of the latter.

If it were any part of my object, in this work, to treat with precision of quantitative analysis, the subjects of the last two paragraphs would have been discussed at considerable length. As it is, I pass them over with these brief notices, referring those who require more ample information on these points, to Dr Faraday's work on *Chemical Manipulation*.

Metallic Reductions effected by Gases.

Hydrogen gas, chlorine gas, and some others, are frequently passed over substances heated in tubes, for the purpose of effecting particular decompositions or reductions. I shall, as an example of this method of experimenting, describe, after Mitscherlich, the reduction of metallic oxides by means of hydrogen gas.

The oxides which become decomposed when heated with hydrogen gas, are pretty numerous, embracing those of cobalt, iron, and copper. Their oxygen combines with the hydrogen and forms water while the metals assume the reguline state.

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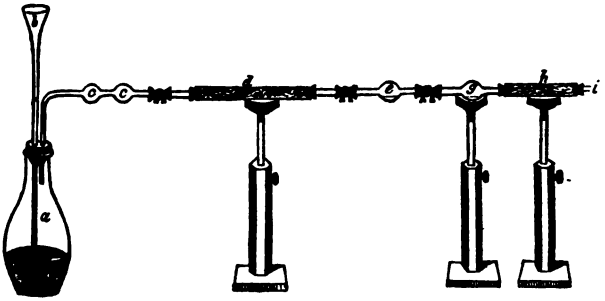

The hydrogen gas is slowly generated in the flask *a*. To separate the aqueous vapour from it, two bulbs, *c c*, are blown upon the delivering tube. The water which does not condense there is fully absorbed by the fused chloride of calcium, with which the drying tube *d* is filled. The gas then passes in a dry state into the bulb *e*. In this bulb is placed the metallic oxide which is to be reduced, oxide of copper, for example. When the apparatus is filled with hydrogen gas, a spirit lamp is applied below the bulb *e*. Only a slight heat is necessary, for when the action of the hydrogen begins to take place, so much heat is produced by the conversion of the oxygen and hydrogen into water, that the solid metallic oxide becomes red hot. The water that is thus produced passes into the bulb *g*, and is there deposited in the liquid state; but to prevent the possible escape of any water with the superfluous current of hydrogen gas which continually issues from the tubes, a second drying tube *h* is added to the apparatus. The excess of hydrogen gas, in a perfectly dry state, then escapes at the point *i*. The bulb *e* is weighed previous to the operation, both empty and when filled with the oxide of copper. The bulb *g*, and the drying tube *h*, are also weighed previous to the operation. When all is ended, the bulb *e* is weighed again with the metallic copper within it. The loss of weight shows the quantity of oxygen which has been abstracted. The bulb *g*, and the tube *h*, are also weighed again. Their increase of weight consists of water. The difference betwixt the weight of the water produced, and the weight of the oxygen lost, shows the weight of the hydrogen which is required to produce a given quantity of water, by combining with a given quantity of oxygen.

This experiment serves therefore to show not only the composition or relative component parts of water, but also the composition of the metallic oxide employed in the operation.

The size of the bulb and tube best adapted for use in experiments of this sort, is shown by the following figure. Nothing but hard German glass can possibly be employed for such an

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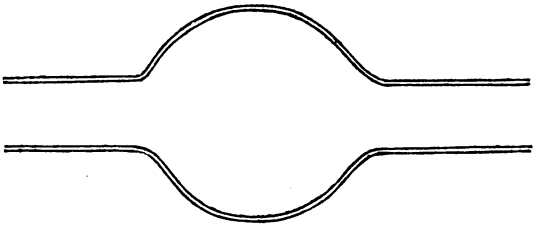
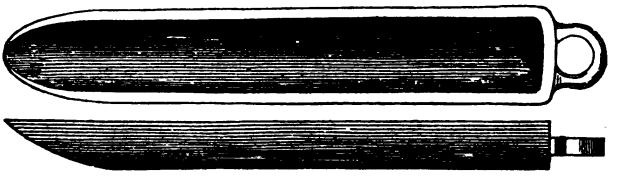
operation. The easy fusibility of flint glass renders it completely useless.



In some cases decompositions of this sort are effected at very high temperatures. It is then necessary to place the solid matter which is to be reduced in a tube of glazed porcelain, and to fix the porcelain tube across a furnace. In other cases, it is useful to place the subject of experiment in a glazed porcelain tray or narrow capsule, such as is represented in the following figures. This gives you the power of weighing it both before



and after the experiment, which is scarcely possible when the substance is placed in a long tube. The ring at the end of the tray is to permit it to be withdrawn from a tube by means of a crooked wire. Such trays can also be employed in exposing powders to heat in an iron tube. Two sizes of these trays of Berlin porcelain are now to be had in Glasgow—

No. 1, three inches long, ... price 8d.
2, four inches long, ... 8d.

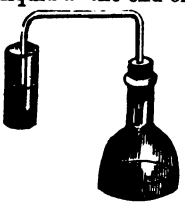
The prices in Glasgow of glazed Berlin porcelain tubes are as follow—

Half-inch wide, 8 inches long, . . . price 2s. 6d.
———————, 13 inches long, ... 4s. 0d.
———————, 26 inches long, ... 6s. 6d.
1¼ inch wide, 15 inches long, ... 8s. 6d.

Solution of Gases.

When gases are prepared for analytical experiments, they are generally made to act upon liquids. In this case, the extreme end of the delivering tube is made to dip into the liquid which is to be exposed to the action of the gas. In proportion as the gas

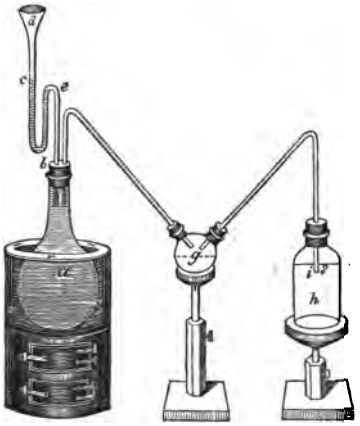
is forced from the flask in which it is generated, it passes into the liquid at the end of the tube, and is there absorbed. The liquid to be acted on by the gas, may be contained either in a test glass, a cylindrical solution jar, or a bottle provided with a glass stopper. The latter is often made use of with advantage when the liquid is to be completely saturated with the gas. When the gas has been passed for some time into the liquid, you withdraw the bottle from the tube, put in the stopper, and shake the bottle. If, upon withdrawing the stopper, there is a rush of air into the bottle, the liquid is still unsaturated; if, on the contrary, there is no rush of air, and the bottle smells strongly of the gas, then the liquid is near the point of saturation.



Experiments of this description are liable to a variety of accidents, unless they are performed with a suitable degree of care. I shall mention these accidents, and the means of preventing them.—1. If the mixture which disengages the gas is thick, and the effervesence so powerful as to force a portion of the mixture into the tube, the bottle may burst, in consequence of the inability of the gas to escape through the obstructed tube. To prevent this, you must, as before directed, put but a small quantity of the mixture into the bottle, and you must keep the action moderate and regular by a suitable application of heat.—2. If the mixture boils over into the liquid which is exposed to the action of the gas, the whole operation is spoiled. To prevent this, you must take notice when the mixture rises up in the bottle, and either remove the lamp from below the bottle, or the liquid from the mouth of the conducting tube.—3. If the disengagement of gas from the mixture happens to slacken, in consequence of the application of too low a degree of heat, or of some other cause, a vacuum is produced in the bottle, and the liquid which is exposed to the gas is forced through the gas tube into the bottle. In this case, the operation is ruined, the liquid lost, and very often the bottle broken. To prevent this, you must keep the tube dipped but a little way into the liquid, so that, when you observe the liquid begin to mount into the tube, you have only to lower the vessel a little, so as to bring the liquid below the mouth of the tube, to avoid the above effect. You must also take care to heat the gas bottle with a steady and regular fire. Remember, that an operation of this sort must never be neglected. You must watch the progress of a distillation as a cat watches a mouse. Your eyes must never be off the vessels, and your hands must never be occupied with any other business than that belonging to the process. A single moment of inattention may ruin the result of many days' labour.

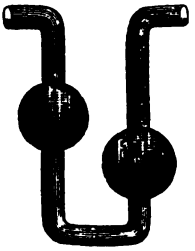
The eagerness with which the solution and the mixture in the gas bottle encroach upon each other's domain are such, that it is advisable, in all experiments of importance, to place an interme-

diate vessel between the other two. This may be a Woulfe's bottle, or a receiver with two necks. The three bottles are connected together by corks and glass tubes. In this case, the solution is less liable to be spoiled, and the gas bottle less liable to be broken, than when the solution and the bottle are connected only by a single tube.



The following apparatus, employed in the preparation of muriatic acid, exhibits an example of the use of the intermediate vessel. The use of the bent funnel or safety tube, I shall describe under the head of Woulfe's apparatus. The rest of this figure will be explained when I come to the article "Muriatic Acid."

In preparing a small quantity of a solution, Mr Davy's bulb is sometimes useful. It affords a pressure which facilitates the saturation of the liquid, but it is a comparatively expensive form of apparatus, and is too easily broken to be fit for common use. It is shown in the margin.

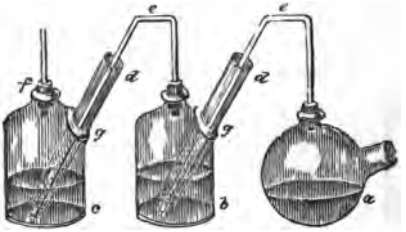


The stone bottle described at page 211 can be employed in preparing solutions of many gases. It should be half filled with liquid. The wide diagonal tube should be pushed into the bottle till it just enters the liquid, but it should not dip far into it. You learn when the point of it is below the liquid by blowing down it. When the tube has been previously fixed in the bottle, you pour water through the wide mouth until you find, by blowing down the tube, that the water covers its lower end. The wide mouth of the bottle is then closed, and the gas delivering tube is passed down the wide diagonal tube till it projects beyond it, whereupon the gas passes clear of the wide tube into the liquid and is absorbed.

Woulfe's Apparatus for Compound Distillation.

In several cases of *distillation*, the substance raised is partly a condensable fluid and partly a gas, which gas is incondensable by itself, but capable of being condensed by being transmitted through a liquid. The apparatus required by a process in which

this double purpose is effected, is represented by the following figure, and is commonly termed Woulfe's apparatus. It is a series of receivers, connected together in a particular manner, and more or less in number, as the case may require. The distilling vessel made use of is the *retort* (page 192), into the tubulure of which, instead of a glass stopper, is inserted the safety tube, of which a description is given below. The first receiver, *a*, is joined to the retort, and has a bent glass tube *e*, open at



both ends, fixed into its tubulure. *b*, the second receiver, is a bottle which, besides its usual neck at the top, has an opening just where its sides fall in to form the top; into which opening a glass tube is fixed diagonally, and the juncture is secured by the application of cement. The lower end of this tube must be about an inch from the bottom of the receiver. *c* is in every respect the same as *b*. The openings spoken of are at *g g*, and the tubes fixed in them are shown by *d d*. The small tube *e*, which rises from the first receiver, passes down the diagonal tube in the second receiver; and another small tube, likewise marked *e*, rising from and cemented into the neck of the second receiver, passes down the diagonal tube in the third receiver. If there were more receivers, they would be like *b* and *c*, and would be connected in the same manner. The lower ends of the tubes *e e* must project as far beyond the ends of the tubes *d d*, as they can do without touching the bottom of the bottles. The liquids by which the gas is to be absorbed are put into the second, and subsequent receivers, each being filled two-thirds full. The nature of this liquid is regulated by the nature of the gas to be absorbed, or by that of the solution intended to be produced. For gases that are rapidly absorbed by water, such as sulphureous acid, &c., distilled water is made use of; for other gases, the carbonic acid, for instance, solution of caustic potash is employed. In general, it is advisable to put water into the second receiver, and the alcaline solution into the third; the *first* receiver, *a*, is always left empty.

The materials being introduced into the retort, the arrangements completed, and the joints secured by cement, the distillation is begun. The condensable vapour collects in a liquid form in

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the receiver *a*, which is kept cool by being placed in water, or by having wet cloths applied to it. In the meantime, the evolved gas passes through the bent tube *e*, into the water contained in *b*, which continues to absorb it, if it is a gas absorbable by water, till it is saturated. When saturation takes place, or when no absorption ensues, the gas bubbles up through the water, passes through the second pipe *e*, and enters the receiver *c*. And so the process continues till the liquids in all the bottles are saturated; and then, if any gas continues to be produced, it escapes through the neck *f* of the last receiver. Should it be required to preserve this overplus gas, it may be conducted into a receiver placed in the pneumatic trough, by fitting into the neck *f* the bent tube figured at page 208.

It will be now proper to point out the use of the tube of safety, figured in the margin, and of the wide diagonally fixed tubes *d d*. Supposing the retort to be closed by a stopper as usual; and supposing the bottles to be destitute of those tubes, and consequently that *e e* were luted into the receivers at *g g*, the process would then be liable to be interrupted by an accident; for if, in consequence of the irregularity of the heat, or other circumstances, a vacuum should be produced in the retort, by the reabsorption of gas, the liquids in the different receivers, being acted upon by the pressure of the atmosphere at *f*, would rush from one into another to supply that vacuum, and by such a mixture of products the whole experiment would be spoiled. If, on the contrary, gas were to be evolved faster than it could be absorbed by the different liquids, or than it could escape at *f*, the apparatus might burst, with considerable danger to the operator. Should the operator close *f* as well as all the other openings, then the apparatus would be destroyed, if either absorption or expansion took place; for, in the one case, the external air would press the vessels till they broke, and in the other, the same effect would be produced by the elasticity of the gas confined within. Now all these inconveniences are obviated by the employment of the different tubes. If an absorption takes place, when these tubes are fixed in the manner that has been described, the vacuum is instantly supplied by the external air, which rushes down the tubes *d d*, into the receivers, and down the tube of safety into the retort. The experiment being thus prevented from failing altogether, at the price of having a small portion of common air mixed with its products. On the other hand, no gas can escape, for any pressure within is instantly followed by a formation of a high column of liquid in the tubes *d d*, which resists the egress of the gas, as long as is consistent with safety.

The *Tube of Safety* is a glass tube about sixteen inches in length, and bent as represented in the above figure. One end of this tube is fastened into a cork, and the other made into the

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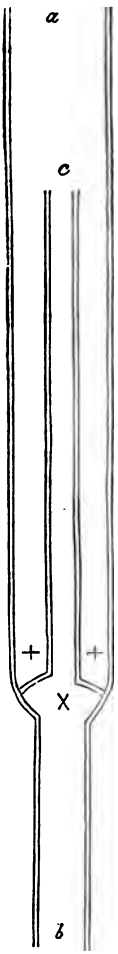
form of a small funnel; *a* is the cork, *b* the funnel. In cases of distillation in which sudden absorption or expansion may take place in the retort, this utensil is fitted into the tubulure of the retort, and the bended part of it, *c c*, is filled with water. Then, if a vacuum happens to be produced in the retort, the external air forces its way through the tube to supply that vacuum; and, on the contrary, if expansion takes place, the elastic fluid gains room by forcing the whole water between *c c* up into the straight part of the tube under the funnel *b*. A number of other uses to which the safety tube is applicable, will be hereafter described in particular experiments.



The Woulfe's apparatus is frequently composed of a series of bottles, resembling the second figure on page 206. In this case the gas delivering tube from the retort is passed through one of the mouths of the first bottle, and made to dip into the liquid which it contains. The other mouth of the bottle is provided with a tube which does not touch the liquid in that bottle, but dips into the liquid in the second bottle, and so on. This apparatus is liable to the accidents described above, which, however, can be generally prevented by a careful attention to the application of heat to the retort. A better method of guarding against accidents, is to use three necked bottles, and to fix in the middle neck of each bottle a tube of 12 inches in length, with a top such as is represented in the margin. The point *b* should dip about half an inch into the liquid contained in the bottle. Then if absorption occurs, common air enters by *a c* x *b*, to supply the vacuum produced, while, if expansion takes place, the half inch of liquid into which the tube *b* dips in the bottle, is driven up *b* x *c* into the space + +, and the superfluous gas escapes at *a*. It will be perceived that the use of the external tube *a* + + is to prevent the loss, which might be important in an analysis, of the half inch of liquid which is forced up the tube *b* by the pressure in the bottle. But when tubes of this particular form are not at hand, a plain tube can be used for the same purpose, the possible loss of a little of the liquid being then submitted to as unavoidable.

The tubes which connect the Woulfe's bottles together in a distillation of this kind, are commonly joined by caoutchouc tubes, as described at page 225.

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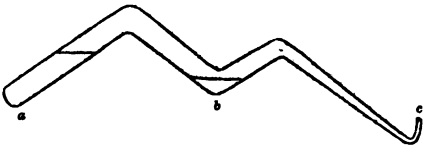
WOULFE'S APPARATUS FOR SMALL EXPERIMENTS.—When it happens that a distillation effected in the small way, yields both a condensable and an incondensable product, and it is necessary to



collect for examination the gas, or incondensable product, as well as the liquid product, you can accomplish that object by employing a vessel such as is represented in the above figure. This is a tube retort similar to that already described at page 194, but the neck of which, after the insertion of the charge, is drawn out and bent before the blowpipe into the form shown by the figure. The mixture submitted to distillation in this vessel is boiled at the end *a*. The condensable vapour which it affords is cooled into a liquid at the bend *b*, in the manner already described at page 194. The incondensable gas then escapes at the mouth *c*, and is passed into tube receivers placed in the mercury trough.

As this apparatus is very difficult to clean, it can scarcely be used for more than one operation. A more economical contrivance, and one which answers equally well for many experiments, consists of the tube retort shown at page 194, connected by means of a cork with a small gas delivering tube.

CONCLUDING NOTICE RESPECTING GASES.

The student should make himself perfectly master of the information relative to the mechanical management of gases here given, and accustom himself to transvase common air with skill before attempting to work with gases. I caution him against putting into operation the experiments of this section, before he has acquired some degree of practical knowledge in other branches of chemistry. Beginners see so many experiments upon gases made during their first visits to the lecture table, and the experiments are generally of so brilliant a description, that they naturally fall into the opinion that they must begin their own operations with the same subjects. This, however, is a mistake. Experiments with gaseous bodies require much more care and experience, much more apparatus, and a much greater outlay of money, and are attended with more danger and disappointment, than the experiments belonging to many other branches of practical chemistry. I would, therefore, recommend a beginner not to trouble himself with repeating experiments upon the gases, until he has been occupied for some time with experiments on solution, evaporation, crystallisation, neutralisation, precipitation,

filtration, &c. He will thus acquire that experience and lightness of hand, which will qualify him to perform more difficult experiments without risk of failure.

It is because I consider the performance of experiments upon gases to be comparatively improper work for a young student of chemistry, that I have treated of the manipulations relative to gases in an extremely (some may consider reprehensibly) summary manner. I have been desirous to make not too large a book, but to give in a small compass a compendium of such information, as appeared to me to be best adapted to promote the object of those engaged either in learning or teaching the elements of practical chemistry. On this ground I consider myself fairly warranted in passing over many subjects, however important, that did not seem to assist my main object, which is a *limited* object, and not intended to embrace the whole circle of chemical knowledge. A complete account of gaseous manipulation would fill a volume. I have restricted it to a few pages, and beg to refer the reader to Dr Faraday's work for longer general descriptions. When, however, I come to treat of the preparation and examination of particular volatile substances, I shall be obliged, and it will then too be the proper time, to enter into various important details.

WEIGHING AND MEASURING.

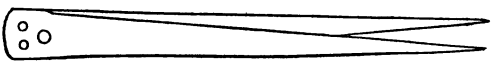
Weighing.—The beginning and end of every exact chemical process consists in weighing; and the best means of ascertaining the weight of bodies is by means of scales, which are therefore indispensable. What are termed apothecaries' scales, are very convenient for students who operate on small quantities, and who do not aspire to the utmost degree of accuracy in their first attempts. They are put up in a little box, which, besides the scales, contains a series of weights, from half a grain to two drachms, in all about 20. These scales are sufficiently accurate for experiments connected with qualitative analysis. The charge made for the box complete is 4s. You must be careful not to use scales, or any other delicate metallic apparatus, in any place where acid vapours are flying about; for if you do, they will be seriously injured.

I have found these apothecaries' scales to possess a high degree of sensibility. A pair which had been employed in ordinary operations for several years, and always without the protection of a glass case, gave, upon being examined, the following results: *a* turned, when not loaded, with $\frac{1}{10}$ of a grain; *b* turned, when loaded with 240 grains in each scale, with $\frac{1}{10}$ of a grain. The beam can be suspended when in use to the triangle of the

retort stand. When not in use, the scales are to be kept in their box.

If a student, who has had some experience in chemistry, wishes to have a more sensible balance, he will be obliged to pay from 30s to 40s for a good one. It is advisable to provide a glass case to protect such a balance from damp, or acid fumes. The glass case must open only at the sides. A balance adapted for use in accurate and important experiments, costs about £12 or £15.

Besides good scales, accurate weights are indispensable. These are best made of brass, or if small, of thin flattened platinum wire. They should be all grain weights, proceeding from $\frac{1}{10}$ of a grain up to 500 grains. A good variety of the small weights are requisite. Thin brass leaf or tin foil, cut into small slips, and crystals of pyrope, a clean and very cheap mineral, are very useful for counterpoises. A pair of very small pincers or forceps, of brass or iron, should be provided to lift up the weights, which ought never to be touched by the fingers, for handling is liable to soil them, and affect their weight. These pincers answer best when they have ivory points.



Every time you are going to weigh, you ought to begin by examining whether your balance is accurate; and if not, you should justify it by putting a bit of wire or paper into the light scale, of sufficient size to make it counterpoise the other scale. The substance to be weighed is placed in one of the scales, and weights are placed in the other till the substance is counterpoised. Or the substance is first counterpoised, then removed from the scale, and weights are put in its place till the balance is again in equilibrium; this method is very good when the accuracy of the balance is doubtful.

When powders are to be weighed, they ought not to be laid on the scale of the balance, but upon a counterpoised watch glass, or what is better, upon very smooth glazed paper, the edges of which ought to be cut with scissors. The powders may be transferred by spatulas formed of platinum, of iron, or of paper. Little ivory paper knives answer this purpose very well. When crucibles are to be weighed after ignition, they ought not to be placed in the scale till sufficiently cool to be handled by the fingers. Volatile liquids must be weighed in closed vessels.

IMPERIAL STANDARD TROY WEIGHT.

grains.		*pennyweights.*		*ounces.*		*pound.*
24	=	1	=	$\frac{1}{20}$	=	$\frac{1}{240}$
480	=	20	=	1	=	$\frac{1}{12}$
5760	=	240	=	12	=	1

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APOTHECARIES' WEIGHT.

pound.		*ounces.*		*drachms.*		*scruples.*		*grains.*
1	=	12	=	96	=	288	=	5760
		1	=	8	=	24	=	480
				1	=	3	=	60
						1	=	20

FRENCH DECIMAL WEIGHT.

Milligramme	=	0·0154 troy grains.
Centigramme	=	0·1540 .....
Decigramme	=	1·5407 .....
Gramme	=	15·4063 .....

MEASURING.—In a great number of experiments, it is necessary to be supplied with a determinate quantity of a liquid; as, for example, an ounce of water. This quantity may be estimated by means of the balance, but a great deal of time is saved by having an instrument by which the ounce of water can be measured. The subjoined figure represents *a graduated jar for measuring liquids*. This is a cylindrical glass vessel, which holds, when filled to a certain mark made near the top, two ounces of distilled water, at the temperature of 60°; that is to say, it holds two ounces of clear cold water. It has other marks all down it, as low as one drachm; so that any quantity of water from one drachm (or, indeed, the half or third of a drachm) to sixteen drachms, may be readily obtained for any required purpose. An *ounce by measure* of any liquid is the bulk of an ounce of water.

Besides the utility of this utensil for measuring water, it may be also employed, when the purpose does not require great accuracy, to measure liquids whose specific gravities are different from that of water. If, for example, you wish to obtain an ounce of sulphuric acid, you proceed as follows:—Knowing that the specific gravity of sulphuric acid is to the specific gravity of water, a little less than as 2 is to 1; and that, consequently, if an ounce of water occupies a certain number of divisions in this tube, then an ounce of the acid can only occupy a little more than half that number; you readily obtain an ounce of sulphuric acid by pouring that liquid into the tube till it rises a little above the mark for ½ an oz. of water. You proceed in like manner for other fluids, calculating the bulk according to the specific gravity. It is by no means intended, by the recommendation of this manner of measuring liquids in general, to do away with more accurate modes; I only point out a method of proceeding calculated to save time in common cases.

TAKING OF SPECIFIC GRAVITIES.

By the term *specific gravity* is understood the density, or quantity of matter under a certain bulk, of one body, compared

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to the density of another. This latter body is assumed as a standard, and the standard to which bodies are generally compared is pure water at the temperature of 60°. In other words, specific gravity is the comparative weights of different sorts of matter. Having found, by a certain process, that a given quantity of water weighs 1000, we employ the same method to ascertain the weight of the same quantity of the metal mercury; we find it to be 13000: thus we have the comparative weights of the same bulk of these two bodies, and we say that the specific gravity of mercury is, to that of water, as 13 to 1. If water at 1000 is assumed as a standard of specific gravities, which, as it has been said, it generally is, then the specific gravity of mercury, given with a reference to the standard, is 13000. The object of finding the specific gravity of bodies, is to distinguish them from each other in one of their most obvious qualities—namely, weight of matter contained in a given space. Students of chemistry have frequent occasion to test the specific gravity of alcohol, acids, and other liquids, because for many purposes these re-agents require to be applied at a particular state of concentration. I proceed to describe the methods by which the specific gravities of different kinds of bodies are determined.

To DETERMINE THE SPECIFIC GRAVITY OF A SOLID, it is weighed, first in air, and then in water. To do this, it is necessary to be provided with very accurate scales, to the bottom of one of which is affixed a small hook, to which the substance is fastened by a fine thread or hair. When the solid, after being weighed in the air, is lowered into the water, it loses of its weight a quantity precisely equal to the weight of its own bulk of water; and hence, by comparing this weight with its total weight, we find its specific gravity. The rule therefore is, divide the total weight by the *loss* of weight in water, the quotient is the specific gravity. Thus, if a mineral weigh 3 ounces in air, and 2 ounces in water, and the *total* weight be divided by the *loss*, which is 1, the quotient, or specific gravity of that mineral, will be 3.

To DETERMINE WITH READINESS THE SPECIFIC GRAVITY OF A LIQUID.—We use for this the SPECIFIC GRAVITY BOTTLE. It is a little globular bottle, with a flat bottom. It has a glass-ground stopper, with a small hole through it. When the bottle is filled with water, or any other liquid, and the stopper put in its place, the superfluous water escapes through the hole, and the bottle remains quite full, without any portion of air. A weight to counterpoise the bottle must be obtained, made of brass or lead. This bottle, when filled with water, contains 500, 1000, or any even number of grains. It is filled with the liquid, the specific gravity of which is required, and then weighed with its contents: the result, deducting the weight of the bottle, is the weight of the liquid under examination, which can then be compared with the weight of water. If, for instance, the bottle holds 1000 grains of water, and 1850 grains of sulphuric acid, then the

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specific gravity of the latter is to that of the former, as 1850 is to 1000.

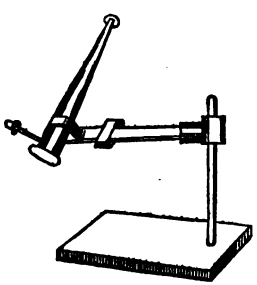
Students will find it useful to use a very thin glass flask, of about half an ounce capacity, and with a long narrow neck, on which a mark can be cut, indicating the space filled by 200 or 250 grains of water. This bottle can be employed to ascertain the specific gravity of small quantities of acids, alcohol, &c.

In taking the specific gravities of bodies, attention should always be paid to their temperature; because the specific gravity of a body when heated is much less than the specific gravity of the same body in a cold state.

A VERY READY WAY TO DETERMINE THE SPECIFIC GRAVITY OF SOLIDS, is to fill a phial with water, and note the weight of the whole accurately in grains. Then to weigh 100 grains of the mineral or other substances to be examined, and drop it gradually into the phial of water. The difference of weight of the phial, with its contents now, and when it was filled with water only, will give the specific gravity of the matter under consideration. For example, if the bottle weighs 50 grains more than it did when filled with water only, it shows that 100 grains of the mineral displace only 50 grains of water, and consequently that its specific gravity is 2000, or twice that of water.

GLASS BLOWING.*

THE most essential instruments for the practice of this art are the Blowpipe and the Lamp.



THE COMMON BLOWPIPE.— Two varieties of the blowpipe are employed in glass-blowing, the simple mouth blowpipe described at page 110, and the table blowpipe, worked by bellows. When the former is used, it must be supported by the tube holder (page 43), so as to leave both your hands at liberty. The nozzle should have a pretty large hole. This blowpipe can, however, for want of power, only be used occasionally in glass-blowing.

* A considerable portion of this article is reprinted from the "ART OF GLASS BLOWING," from the French of "Danger," a work of which but a small impression was printed, and which is now scarce.

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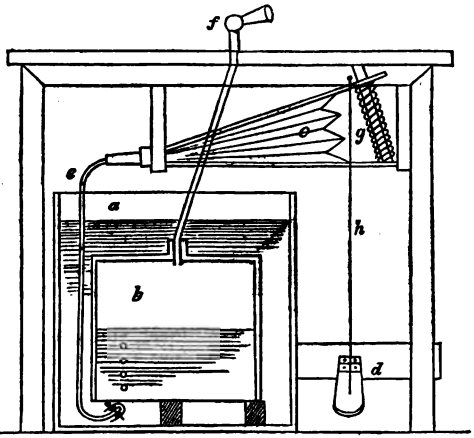
TABLE BLOWPIPE.—The construction of this apparatus is shown by the following diagram. *a* is a cylindrical vessel, open at the top, and containing water. *b* is a similar vessel, open at the bottom, but provided with a neck at the top. These vessels



may be made of tinplate, but answer better when made of stoneware, because the tinplate is soon destroyed by rust. *c* is an ordinary kitchen bellows, the under board of which is fixed in a horizontal position below the work table, by fillets which connect it with the frame. *g* is a round rod of wood, one end of which is fixed to the under handle of the bellows, and the other end to the under side of the top of the table, in the direction shown by the figure. This rod passes through a hole in the upper handle of the bellows, but is not attached to it. A coil of strong iron wire ($\frac{1}{8}$ inch thick) is put round the wooden rod, between the two handles of the bellows, but is not attached either to the handles or the rod. *h* is a string fixed to the upper handle of the bellows, passed through a hole in the under handle, and fastened at the other end to the treadle *d*. *e* is a leaden pipe, affixed to the nozzle of the bellows, and terminating below the opening of the inverted cylinder *b*. This end of the pipe has a slip of waxed silk tied loosely over it to prevent the back pressure of water into the bellows. *f* is a leaden pipe fixed air tight into the neck of the cylinder *b*, and passing upwards through a cork fixed in a hole in the table.

When left at rest, the bellows is kept open by the spring of the coiled wire on the rod *g*. The vessel *b* is then full of water, and without air.

When the treadle *d* is forced down by the foot, the coiled wire gives way, the bellows is compressed by the action of the cord *h*,

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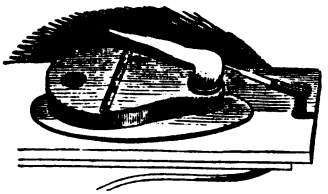
and air is forced through the pipe *e* into the vessel *b*, while the water rises in the vessel *a*, and produces a pressure upon the air in the vessel *b*. Reiteration of this process forces so much air into the vessel *b*, and so much water into the vessel *a*, that the blast which issues from the pipe *f* soon becomes forcible and steady. This pipe is provided with blowpipe nozzles, and the jet of air is then ready to act upon the flame of the lamp.

THE GLASS BLOWER'S LAMP.—It is made of tinplate, of an oval or pear shape, 7 inches long, 1½ inch deep, and provided with a shallow tray of somewhat similar form, but larger size, the use of which is to catch overflowing oil. The wick holder is of an oval shape, and measures 1½ inch lengthways, and ¾ inch crossways. The wick should be of clean cotton yarn. The best combustible is *droppings of sweet oil.* The wick should be kept clean, and cut very level, and should be divided into two equal portions, to give a free passage to the current of air from the blowpipe. This division of the wick is best managed by placing a tin partition across the wick holder, so as to produce a combination of two wicks.



It has been observed that cotton, which has been for some time exposed to the air, no longer possesses the good properties for which glass blowers esteem it. The alteration of the cotton is probably brought about by the dust and water which the air always holds in suspension. Such cotton burns badly, forms a bulky coal, and permits with much difficulty, the capillary ascension of the liquid which serves to support the flame; so that it is impossible to obtain a good fire, and necessary to be incessantly occupied in snuffing the wick. Cotton is equally subject to alteration when lying in the lamp, even though impregnated with oil. You should avoid making use of wicks that are too old. When you foresee that you will remain a long time without having occasion to employ the lamp, pour the oil into a bottle, which can be corked up, and let the wick be destroyed, previously squeezing from it the oil which it contains.

It is indispensable to make use of none but new and good cotton; it should be clean, soft, fine, and not twisted. It is best to preserve it in boxes, after having folded it in many double papers, to exclude dust and moisture. When you wish to make wicks, take a skein of cotton and cut it into four or six pieces, dispose them side by side in such a manner as to make a bundle more or less thick, and eight or ten inches in length; pass a large comb lightly through the bundle, to lay the threads even, and tie it gently at each end, to keep the threads from getting entangled.

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A wick of the size here prescribed should rise ¾ of an inch—never more than an inch—above the surface of the oil.

When you have the command of gas, the burner represented at page 114 will be found useful. The neck *a* of this burner fits most common gas sockets prepared for single jets. When this burner is used for glass blowing, the point + must be turned towards you, and the point *c* farthest away, so as to place the orifice + *c* in a line before you.

JETS OR NOZZLES.—The point of your blowpipe should be formed in such a manner that you can fix upon it various little jets, or nozzles, the orifices in which, always perfectly round, ought to vary in size according to the bulk of the flame upon which you desire to act. The best way to manage this is to let the pipe *f* (page 239) terminate at the surface of the table, and to attach to it a bent brass tube such as is shown in the wood cut which represents the lamp, page 240, the upper opening of which brass tube should spread a little outwards, to facilitate the adjustment of small nozzles by the intermediation of soft paper or corks.

You cannot, without this precaution, obtain the maximum of heat which the combustion of the oil is capable of affording. This employment of little moveable jets offers the facility of establishing a current of air, greater or smaller, according to the object you wish to effect; above all, it allows you to clean with ease the cavity or orifice of the beak, as often as it may be necessary.

These jets can be made of different materials. It is most advisable to have them made of copper or brass; those which are formed of tin plate (white iron), and which are commonly used in chemical laboratories, are the worst kind of all. They soon become covered with grease or soot, which either completely closes up the orifices, or, at least, very soon alters the circular form which is necessary to the production of a good fire. Glass jets are less liable to get dirty, and are much cheaper than the above; but, on the other hand, they have the disadvantage of being easily melted. This can to a certain extent be remedied by making the points of very thick glass, and by always keeping them at some distance from the flame. Moreover, as you can make them yourself when you are at leisure, their use is very commodious.

Another method of affixing jets to the hydrostatic blowpipe, may be that described at page 110, in reference to the mouth blowpipe. The leaden pipe *f*, page 239, may be soldered to a brass pipe *c*, page 110, and the latter be capped by such jets as *d*, page 110. The pipe *f* may, as I have said at page 239, pass up through a hole in the table, and be fixed in that hole by a cork; or, where it is not expedient to perforate the table, the pipe may be steadied by being tied to a wooden clamp screwed to the edge of the table,—the bellows and blowpipe being in that case fitted together, but not fixed to the table.

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Of whatever material the beak may be made, its orifice must be perfectly round, and the *size* of the orifice, as I have before observed, must have a relation to the size of the wick which is to be used with it. The diameter of the orifice of the jets best adapted for use with a wick of the size prescribed above, is the *twelfth of an inch.*

When soot is deposited on a glass jet, you must replace it by a new jet, and then clean it by burning off the soot in the flame; but you must take care not to let the glass get softened during the cleaning, otherwise the jet will be spoilt, for a sharp well defined orifice is indispensable to the production of a good flame.

Means of Obtaining a Good Flame.—It is only by long habitude, and a species of routine, that workmen come to know, not only the kind of flame which is most proper for each object they wish to make, but the exact point of the jet where they ought to expose their glass.

When the orifice of the blowpipe is somewhat large, or when (the orifice being capillary) the current of air is very strong, or the beak is somewhat removed from the flame, the jet of fire, instead of being prolonged into a pointed tongue, is blown into a brush. It makes then a roaring noise, and spreads into an irregular figure, wherein the different parts of the flame are confounded beyond the possibility of discrimination. This flame is very proper for working glass tubes; it ought to be clear and very brilliant, and above all, it should not deposit soot upon cold bodies suddenly plunged into it. The *maximum* of temperature in this flame is not well marked; I may say, however, that in general it will be found at about two-thirds of the whole length of the flame from the jet. As this roaring flame contains a great quantity of carburetted hydrogen, and even of vapour of oil, escaped from combustion, it possesses a disoxidising or reducing property in a very high degree.

The lamp should be firmly seated upon a steady and perfectly horizontal table, and should be kept continually full of oil. The oil which escapes during the operation, from the lamp into the tin stand placed below it, should be taken up with a glass tube having a large bulb, and returned to the lamp.

When you set to work, the first thing you have to do is to examine the orifice of the beak. If it be closed, or altered in form, by adhering soot, you must carefully clean it, and open the canal by means of a needle or fine wire. In the next place, you freshen the wick by cutting it square, and carrying off with the scissors the parts that are carbonised. You then divide it into two principal bundles, which you separate sufficiently to permit a current of air, directed between the two, to touch their surface lightly, without being interrupted in its progress. By pushing the bundles more or less close to one another, and by snuffing them, you arrive at length at obtaining a convenient flame. It is a good plan to allow, between the two principal bundles and at

their inferior part, a little portion of the wick to remain: you bend this down in the direction of the jet, and make it lie immediately beneath the current of air. When you once get a good flame, you take particular care not to alter the position of the lamp or blowpipe, for everything depends upon this position, and a hair's breadth of alteration often makes or mars a good flame.

The wick must be prevented from touching the rim of the lamp, in order to avoid the running of the oil into the stand of the lamp. This is easily managed by means of a bent iron wire, brought down round the wick and level with the surface of the lamp. A few drops of oil of turpentine spread upon the wick, makes it take fire immediately over its whole extent, on the approach of an inflamed substance.

To obtain a good flame, it is necessary to place the lamp in such a position that the orifice of the blowpipe shall just touch the exterior part of the flame. The beak must not enter the flame, as it can then throw into the jet only an inconsiderable portion of the ignited matter. On the other hand, if the lamp be too far away from the blowpipe, the flame becomes trembling, appears blueish, and possesses a very low degree of heat.

The flame should be directed upwards at an angle of 20 or 25 degrees, as exhibited by the cut at page 240.

The current of air ought to be constant, uniform, and sufficiently powerful to carry the flame in its direction. The point to which you should apply, in the use of these instruments, is to enable yourself to produce a current of air so uniform in its course that the projected flame be without the least variation.

Finally, when you leave off working, you should extinguish the flame by cutting off the inflamed portion of the wick with the scissors. This has the double advantage of avoiding the production of a mass of smoke and of leaving the lamp in a fit state for another operation.

Places Fit to Work in.—Every place is adapted for a work shop, provided it be not too light and the air be tranquil. The light of the lamp enables one to work with more safety than day light, which does not permit the dull red colour of hot glass to be seen. Currents of cold air are to be avoided, because they occasion the fracture of glass exposed to them on coming out of the flame.

Choice of Glass Tubes.—The only materials employed in the fabrication of the objects described in this treatise, are tubes of hard glass or of flint glass. They can be had of all diameters, and of every variety of thickness. They are commonly about three feet long, but some are found in commerce which are six feet in length. You should choose tubes that are very uniform —that is to say, straight, and perfectly cylindrical, both inside and outside. A good tube should have the same diameter from

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one end to the other, and the sides or substance of the glass should be of equal thickness in every part. This is indispensable when the tubes are to have spherical bulbs blown upon them.

The substance of the glass should be perfectly clear, without blebs, or specks, or stripes. The tubes are so much the more easy to use, as the glass of which they are made is the more homogeneous. Under this point of view, the white glass, known in commerce by the name of crystal or flint glass, is preferable to hard glass: it is more fusible, less fragile, and less liable to break under the alternations of heat and cold: but it is dearer and heavier, and has the serious disadvantage of becoming permanently black when exposed to a certain part of the flame.

The best hard white glass tubes are made in Bohemia. They are formed of potash and lime in combination with silica. The best soft white glass tubes are made in France. They consist of soda in combination with silica. Both of these sorts are free from lead. In England, it is seldom possible to get made any other sort of glass tubes than those of flint glass. Chemists have therefore to import tubes for experimental purposes from the continent, as it rarely happens that flint glass tube vessels can be employed with confidence or success.

You must take care never to employ flint glass for instruments which are to be submitted to the action of certain fluids—such as sulphuretted hydrogen, and the hydro-sulphurets; for these compounds are capable of decomposing flint glass, in consequence of its containing oxide of lead. In general, hard German glass is preferable to flint glass for all instruments which are to be employed in chemistry. Flint glass should only be used for ornamental objects, and for barometers, thermometers, and other instruments employed in philosophical researches.

Preparation of Tubes before heating them.—Before presenting a tube to the flame, you should clean it well both within and without, in order to remove all dust and humidity. If you neglect to take this precaution, you run the risk of cracking or staining the glass. When the diameter of the tube is too small to permit of your passing a plug of cloth or paper to clean its interior, you can accomplish the object by the introduction of water, which must, many times alternately, be sucked in and blown out, until the tube is deemed clean. One end of it must then be closed at the lamp, and it must be gradually exposed to a charcoal fire, where, by raising successively all parts of the tube to a sufficiently high temperature, you endeavour to volatilise and expel all the water it contains. In all cases you considerably facilitate the disengagement of moisture by renewing the air in the tube by means of a bottle of Indian rubber fastened to the end of a long narrow tube, which you keep in the interior of the tube to be dried during the time that it is being heated.

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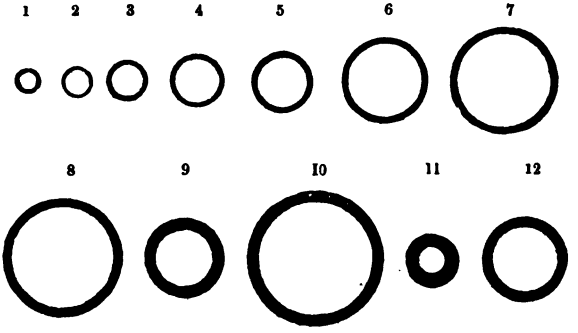
You can here advantageously substitute alcohol for water, as being much more volatile, and as dissolving greasy matters; but these methods of cleansing should only be employed for valuable objects, because it is extremely difficult fully to expel moisture from a tube wherein you have introduced water, and because alcohol is too expensive to be employed where there is no particular necessity.

When the tubes no longer contain dust or moisture, you measure them, and mark the divisions according to the sort of work which you propose to execute.

Sizes of Glass Tubes.—It may be useful to give cross sections of the most useful sizes of glass tubes, with notices of the chemical vessels, or parts of vessels, for which they best answer. Here they are:



Nos. 1 to 5. *Hard.* Closed subliming tubes for arsenic and other volatile substances, pages 104, 132. Open subliming tubes for use with the blowpipe, page 160. Little matrasses for the sublimation of water, page 10, *b*, page 106, *i*.

Nos. 1 to 5. *Soft.* Gas delivering tubes, pages 194 and 208. Dropping tubes, page 58. Tube funnels, page 15.

Nos. 6, 7, 8. *Hard.* Test tubes, page 8, *c*, page 10, page 49. Bulb tubes, page 8, *a*, *b*. Tube retorts, pages 193 and 206.

Nos. 6, 7, 8. *Soft.* These also can be used for test tubes, but very rarely can be procured sufficiently thin in the glass, to answer so well as the hard tubes. Strong tubes of these sizes, and 2 or 3 inches long, sealed at one end, and bordered at the other, are very useful as bottles for the preservation of small quantities of valuable substances. Nos. 6 and 7, serve for the wide part of dropping tubes.

Nos. 8, 10. *Soft.* Cooper's Gas Receiver, page 219. Drying tubes for gases, page 224. Bent gas receiver, page 220.

Nos. 9, 12. *Hard.* For the preparation of bulb retorts, page 10, and 200, and for bulb decomposing tubes, page 227.

Nos. 9. *Soft.* Bulb tubes and retorts for boiling liquids in,

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but not for preparing gases, or for any case of exposure to high temperature with dry charges in them.

Nos. 7, 8, 10. *Hard.* Tubes for organic analysis by combustion with oxide of copper. Tube retorts, page 206.

No. 10. *Soft.* Condensing tubes of the large distilling or rather cooling apparatus, page 201.

No. 11. *Soft.* Gas delivering tubes for ordinary use. This size makes a pretty substantial tube. It also serves for strong stirrers when closed at the ends, page 48.

Nos. 7, 8, 9, 12. *Soft.* Gas receivers to be used with the mercury trough, page 218. They should be 6 inches long, sealed at one end, and ground flat at the other, so as to be capable of being closed by the pressure of a finger.

METHOD OF PRESENTING TUBES TO THE FLAME AND OF WORKING THEM THEREIN.—The two arms are supported on the front edge of the table, and the tube is held with the hands either above or below, according as it may be necessary to employ more or less force, more or less lightness. You ought, in general, to hold the tube *horizontally*, and in such a manner that its direction may be perpendicular to that of the flame. Yet, when you wish to heat at once a large portion of the tube, or to soften it so that it shall sink together in a particular manner, as in the operation of sealing, you will find it convenient to *incline* the tube, the direction of which, however, must always be such as to turn the heated part continually towards you.

I am about to give a general rule upon the observance of which I cannot too strongly insist, as the success of almost every operation entirely depends upon it. The rule is, *never to present a tube to the flame without* CONTINUALLY TURNING *it;* and turning it, too, with such a degree of rapidity that every part of its circumference may be heated and softened to the same degree. As melted glass necessarily tends to descend, there is no method of preventing a heated tube from becoming deformed but that of continually turning it, so as to bring the softened part very frequently uppermost. When you heat a tube near the middle, the movement of the two hands must be *uniform* and *simultaneous*, or the tube will be twisted and spoiled.

When the tubes have thick sides, they must not be plunged *into* the flame until they have previously been strongly heated. You expose them at first to the current of hot air at some inches from the extremity of the jet; you keep them there some time, taking care to turn them continually, and then you gradually bring them towards, and finally into, the flame. The thicker the sides of the tubes are, the greater precaution must be taken to elevate the temperature gradually: this is the only means of avoiding the fractures which occur when the glass is too rapidly heated. Though it is necessary to take so

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much care with large and thick tubes, there are, on the contrary, some tubes so small and so thin that the most sudden application of the fire is insufficient to break them. Practice soon teaches the rule which is to be followed with regard to tubes that come between these extremes.

Hard glass ought to be fused at the *maximum* point of heat; but glass that contains oxides capable of being reduced at that temperature (such as flint glass) requires to be worked in that part of the flame which possesses the highest oxidating power. If you operate without taking this precaution, you run the risk of decomposing the glass. Thus, for example, in the case of flint glass, you may reduce the oxide of lead, which is one of its constituents, to the state of metallic lead. The consequence of such a reduction is the production of a black and opaque stain upon the work, which can only be removed by exposing the glass, during a very long time, to the extremity of the jet.

You must invariably take the greatest care to keep the flame from passing into the interior of the tube; for when it gets there it deposits a greasy vapour, which is the ordinary cause of the dirt which accumulates in instruments that have been constructed without sufficient precaution as to this matter.

In order that you may not blacken your work, you should take care to snuff the wick of the lamp whenever you perceive the flame to deposit soot.

You can judge of the *consistence* of the tubes under operation as much by the *feel* as by the *look* of the glass. The degree of heat necessary to be applied to particular tubes, depends entirely upon the objects for which they are destined. As soon as the glass begins to feel soft, at a *brownish red heat*, for example, you are at the temperature most favourable to good *bending*. But is it intended to *blow a bulb*? The glass must, in this case, be completely melted, and subjected to a full *reddish white heat*. I shall take care, when speaking hereafter of the different operations to be performed, to mention the temperature at which *each* can be performed with most success.

When an instrument upon which you have been occupied, is finished, you should remove it from the flame *gradually*, taking care to *turn* it continually, until the glass has acquired sufficient consistence to support its own weight without becoming deformed. Every instrument formed thus of glass requires to undergo a species of *annealing*, to enable it to be preserved and employed. To give the instrument this annealing, it is only necessary to remove it from the flame very gradually, allowing it to repose some time in each *cooler* place to which you successively remove it. The thicker or the more unequal the sides of the glass, the more carefully it requires to be annealed. No instrument should be permitted to touch cold or wet bodies while it is warm.

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FUNDAMENTAL OPERATIONS IN GLASS BLOWING.—All the modifications of shape and size which can be given to tubes in the construction of various instruments, are produced by a very small number of dissimilar operations. I have thought it best to unite the description of these operations in one article, both to avoid repetitions and to place those who are desirous to exercise this art in a state to proceed, without embarrassment, to the construction of any instrument of which they may be provided with a model or a drawing; for those who attend properly to the instructions given here, with respect to the fundamental operations of glass blowing, will need no other instructions to enable them to succeed in the construction of all kinds of instruments that are capable of being made of tubes. These fundamental operations can be reduced to ten, which may be named as follows:—

1. Cutting.	6. Sealing.
3. Bordering.	7. Blowing.
2. Widening.	8. Piercing.
4. Drawing out.	9. Bending.
5. Choking.	10. Soldering.

I proceed to give a detailed account of these different operations.

1.—GLASS CUTTING.

The different methods of cutting glass tubes, which have been contrived, are all founded on two principles; one of these is the division of the surface of glass by cutting instruments, the other the effecting of the same object by a sudden change of temperature; and sometimes these two principles are combined in one process.

The first method consists in notching the tube, at the point where it is to be divided, with the edge of a Lancashire crossing file, or with a thin plate of cast steel having a rough edge prepared by rubbing it on a sandstone or a sanded board. The nails of the two thumbs are then placed against the cut in the tube, but upon the opposite side of the tube, the cut being turned *from you*, and at the same instant the two ends of the tube are pulled asunder, while the thumb nails are pressed against the tube opposite to the notch. This method is sufficient for the division of small tubes, such as Nos. 1 to 6, page 245. Larger and thicker tubes, Nos. 7 to 10, need to be *sawed into* by the steel blade; and when they are very thick or large, the notch requires to be carried even half way round the tube. You can also employ a fine iron wire stretched in a bow, or, still better, the glass cutters' wheel; with either of which, assisted by a mixture of emery and water, you can cut a circular trace round a large tube, and then divide it with ease.

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When the portion which is to be removed from a tube is so small that you cannot easily lay hold of it, you cut a notch with a file, and expose the notch to the point of the blowpipe flame: the cut then flies round the tube.

This brings us to the second method of cutting tubes—a method which has been modified in a great variety of ways. It is founded on the property possessed by vitrified matters, of breaking when exposed to a sudden change of temperature. Acting upon this principle, some artists apply to the tube, at the point where they desire to cut it, a band of fused glass. If the tube does not immediately separate into two pieces, they give it a slight smart blow on the extremity, or they drop a little water on the heated ring. Other glass blowers make use of a piece of iron heated to redness, an angle or a corner of which they apply to the tube at the point where it is to be cut, and then, if the fracture is not at once effected by the action of the hot iron, they plunge the tube suddenly into cold water.

The two methods here described can be combined. After having made a notch with a file, or the edge of a flint, you introduce into it a little water, and bring close upon it the point of a very little tube previously heated to the melting point. This double application of heat and moisture obliges the notch to fly right round the tube.

You may cut small portions from glass tubes in a state of fusion, by means of common scissars.

The necks of the large retorts and flasks are cut off by means of a ring of iron fastened to the end of an iron rod, several of which rings of various sizes should be found in a laboratory. A ring of the proper size for the object being chosen, it is brought to a full red heat, and stuck upon the neck which is to be cut. After a minute, it is taken off and a few drops of cold water or a wet stick is applied to the heated glass; upon which the neck immediately flies off.

Another and better method of cutting off the necks of thick glass vessels, is by means of *pastile glass cutters*, which are prepared as follows: Take of gum arabic 1 part, of gum tragacanth 1 part, and digest them in hot water till you obtain a slimy mass. The mixture must make 10 parts. Add ½ part of gum benzoin dissolved in the smallest possible quantity of alcohol, and 10 or 12 parts of extremely well pulverised charcoal. Mix the whole intimately together, work the mass into a stiff paste, roll it between two boards rubbed over with charcoal powder, into cylinders ¼ inch thick and 8 inches long, and let them dry.

It is of importance to have the charcoal thoroughly pulverised and sifted, and well kneaded with the other ingredients.

These pastile glass cutters when heated at one end, continue to burn like an ordinary fumigating pastile, producing a red-hot point, by means of which a crack in a glass can be led in any direction with as much certainty as a line can be drawn with a pen. When the glass that is to be cut has no crack, it is ne-

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ccssary to make a scratch with a file, and then spring it open by approximating the heated pastile. When you wish to cut off the neck of a flask so as to obtain both pieces of the vessel in an unbroken state, or when you wish to cut a flask across the middle without first commencing at the edge and so bringing down a vertical split, you obtain your object by first making a scratch or cut on the flask with a file, in the direction of the desired fracture. You then hold the lighted pastile close to the glass, and at a little distance (the eighth of an inch) from the end of the scratch, and in the direction in which you wish the split to be extended, and you push the pastile slowly towards the scratch till the split takes place, which generally is to the extent of the heated portion. You then again remove the pastile to the eighth of an inch from the end of the split, and again push it towards the split; upon which a second extension takes place. The same operation can be repeated till the split has taken the whole course you desire it to do. It is useful to make an ink line, or to tie a thread round the vessel, to guide the pastile in a right line. With a little exercise you will become able to cut glass in this manner as straight and as neatly as by the use of a rule and diamond. When the pastile is first lighted it must be allowed to burn to a point before you attempt to cut glass with it. When you have finished your operation, you extinguish the fire by plunging the pastile into dry sand.

How to Bore Holes in Glass.—Hard steel tools, such as drills, files, rasps, &c., cut glass with extraordinary facility when thoroughly wetted with a solution of camphor in oil of turpentine. With a sharp three edged drill, and a drill bow, holes can be bored easily, and still better when the drill is fixed on a lathe, as rapid motion is useful. The drill can nevertheless be effectively used by the hand alone, but an abundant supply of the camphorised oil of turpentine must be applied to the cutting tool during the operation. In the same manner, a hole, when once made, can be readily enlarged by a round file, the ragged edges of tubes or glass plates can be removed by a flat file, female screws can be cut in thick plates of flint glass, flat window glass can be sawed by a saw made of a watch spring; and, in short, glass, brittle and refractory as it is, yields so effectually to the action of camphorised oil of turpentine, as to prove almost as readily workable with cutting tools as brass itself.

2.—Bordering.

To whatever use you may destine the tubes which you cut, they ought, almost always, to be bordered. If you merely desire that the edges shall not be sharp, you can smoothen them with the file wetted with camphorised oil of turpentine, or, what is better, you can expose them to the flame of the lamp until they are rounded. If you fear the sinking in of the edges when they are in a softened state, you can hinder this by working in the interior of the tube a round rod of iron, one-sixth of

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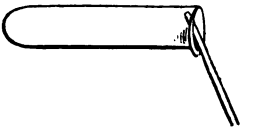
an inch thick; and one end of which should be filed to a conical point, and the other end be inserted into a thin, round, wooden handle. You will find it convenient to have a similar rod with a slight bend in the middle.

When you desire to make the edges of the tube project, bring the end to a soft state, then insert in it a metallic rod, and move it about in such a manner as to widen a little the opening. While the end of the tube is still soft, place it suddenly upon a horizontal surface, or press it by means of a very flat metallic plate. The object of this operation is to make the end of the tube flat and uniform. The metallic rod which you employ may be the same as I have described in the preceding paragraph. Instead of agitating the rod in the tube, you may hold it in a fixed oblique position, and turn the tube round with the other hand, taking care to press it continually and regularly against the rod. See the figure. Very small tubes can be bordered by approaching their extremities to a flame not acted upon by the blowpipe; particularly the flame of a spirit lamp.



The edges of flasks and of thick tubes can be most readily bordered by means of a stick of hard and well burnt charcoal, cut into the form shown by the marginal figure, and having both a blunt point and a narrow point, to suit openings of different sizes.

When the edges of a tube are to be rendered capable of suffering considerable pressure, you can very considerably augment their strength by soldering a rib or string of glass all round the end of the tube. Holding the tube in the left hand, and the string of glass in the right, you expose them both at once to the flame. When their extremities are sufficiently softened, you attach the end of the rib of glass to the tube at a very short distance from its extremity; you then continue gradually to turn the tube, so as to cause the rib of glass to adhere to it, in proportion as it becomes softened. When the rib has made the entire circumference of the tube, you separate the surplus by suddenly darting a strong jet of fire upon the point where it should be divided; and you continue to expose the tube to the flame, always turning it round, until the ring of glass is fully incorporated with the glass it was applied to. You then remove the instrument from the flame, taking care to anneal it in so doing. During the operation, you must take care to prevent the sinking together of the sides of the tube, by now and then turning the iron rod in the interior. It is a *red heat*, or a *brownish red heat* that is best adapted to this operation.

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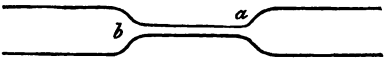
3.—Widening.

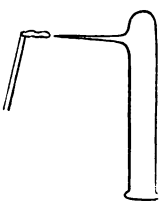
When you desire to enlarge the diameter of the end of a tube, it is necessary, after having brought it to a soft state, to remove it from the flame, and to press the sides of the glass outwards by means of a large rod of iron with a conical point. The tube must be again heated, and again pressed with the conical iron rod, until the proper enlargement is effected. This operation is much the same as that of bordering a tube with projecting edges.

4.—Drawing Out.

You can *draw out* or *contract* a tube either in the middle or at the end. Let us in the first place consider that a tube is to be drawn out in the middle. If the tube is long, you support it with the right hand *below*, and the left hand *above*, by which means you secure the force that is necessary, as well as the position which is commodious, for turning it continually and uniformly in the flame. It must be kept in the jet till it has acquired *a cherry red heat*. You then remove it from the flame, and always continuing gently to turn it, you gradually separate the hands from each other, and draw the tube in a straight line. In this manner you produce a long thin tube in the centre of the original tube, which ought to exhibit two uniform cones where it joins the thin tube, and to have the points of these cones in the prolongation of the axis of the tube.



To draw out a tube at its extremity, you heat the extremity till it is in fusion, and then remove it from the flame; you immediately seize this extremity with the pliers, and at the same time separate the two hands. The more rapidly this operation is performed, the glass being supposed to be well softened, the more capillary will the drawn-out point of the tube be rendered. Instead of pinching the fused end with the pliers, it is simpler to bring to it the end of a little auxiliary tube, which should be previously heated, to fuse the two together, and then to draw out the end of the original tube by means of the auxiliary tube. In all cases, the smaller the portion of tube softened, the more abrupt is the part drawn out.



When you desire to draw out a point from the side of a tube, you must heat that portion alone, by holding it fixedly at the extremity of the jet of flame. When it is sufficiently softened, solder to it the end of an auxiliary tube, and then draw it out. The annexed figure exhibits an example of a tube drawn out laterally. A *red heat*, or a *cherry red heat*, is best adapted to this operation.

5.—Choking.

I do not mean by *choking*, the closing or stopping of the tube, but simply a diminution of the interior passage or bore. It is a sort of contraction. You perform the operation by presenting to the flame a zone of the tube at the point where the contraction is to be effected. When the glass is softened, you draw out the tube, or push it together, according as you desire to produce a hollow in the surface of the tube, or to have the surface even, or to cause a ridge to rise above it. A *cherry red heat* is the proper temperature to employ.

6.—Sealing.

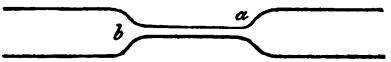
If the sides of the tube to be sealed are thin, and its diameter is small, it is sufficient to expose the end that you wish to close to the flame of the lamp. When the glass is softened it sinks of itself, in consequence of the rotatory motion given to it, towards the axis of the tube, and becomes rounded. The application of no instrument is necessary.

If the tube is of considerable diameter, or if the sides are thick, you must soften the end, and then, with a metallic rod or a flat pair of pliers, mould the sides to a hemisphere, by bringing the circumference towards the centre, and continuing to turn the tube in the flame, until the extremity is well sealed, and perfectly round. Examples of the figure are to be seen in fig. *c*, page 8, and fig. *a*, page 10. Instead of this method, it is good, when the extremity is sufficiently softened, to employ an auxiliary tube, with the help of which you can abruptly draw out the point of the original tube, which becomes by that means cut and closed by the flame. In order that this part may be well rounded, you may, as soon as the tube is sealed, close the other extremity with a little wax, and continue to expose the sealed part to the flame, until it has assumed the form of a *drop of tallow*. Fig. 6, page 104. You can also seal in this fashion, by blowing, with precaution, in the open end of the tube, while the sealed end is in a softened state.

If you desire the sealed part to be flat, you must press it, while it is soft, against a flat substance. If you wish it to be concave, like the bottom of a bottle, you must suck air from the tube with the mouth; or, instead of that, force the softened end inwards with a metallic rod. You may also draw out the end till it be conical, as figs. 4, 5, page 104, or terminate it with a little button. In some cases the sealed end is bent laterally, as fig. 4, page 104; in others it is twirled into a ring, having previously been drawn out and stopped in the bore. In short, the form given to the sealed end of a tube can be modified in an infinity of ways, according to the object for which the tube may be destined.

In preparing test tubes like fig. *c*, page 8, you begin by cutting the long glass by means of the pastile cutter, into lengths equal to two tubes. You then *draw out* each of these pieces of

tube in the middle, so as to produce a short narrow tube *b a*. If the glass at *a* is now held steadily in the flame, and the piece



b is pulled away, the other tube melts together at *a*. This closed end is then turned in the flame, till it becomes uniformly round and thick.

You should take care not to accumulate too much glass at the place of sealing. If you allow it to be too thick there, you run the risk of seeing it crack during the cooling. The operation of sealing succeeds best at a *cherry red heat.*

7.—Blowing.

The construction of a great number of philosophical instruments requires that he who would make them should exercise himself in the art of blowing *bulbs* possessing a figure exactly spherical. This is one of the most difficult operations of the art.

To blow a bulb at the extremity of a tube, you commence by sealing it; after which you collect at the sealed extremity more or less glass, according to the size and the solidity which you desire to give to the bulb. When the end of the tube is made thick, completely sealed, and well rounded, you elevate the temperature to a *reddish white* heat, taking care to turn the tube continually and rapidly between your fingers. When the end is perfectly soft, you remove it from the flame, and, holding the tube horizontally, you blow quickly with the mouth into the open end, without discontinuing for a single moment the movement of rotation. If the bulb does not by this operation acquire the necessary size, you soften it again in the flame, while under the action of which you turn it very rapidly, lest it sink together at the sides, and become deformed. When it is sufficiently softened you introduce, in the same manner as before, a fresh quantity of air. It is of importance to observe that, if the tube be of large diameter, it is necessary to contract the end by which you are to blow, in order that it may be turned round with facility while in the mouth.

When the bulb which you desire to make is to be somewhat large, it is necessary, after having sealed the tube, to soften it for the space of about half an inch from its extremity, and then, with the aid of a flat piece of metal, to press moderately and repeatedly on the softened portion, until the sides of the tube which are thus pressed upon, sink together, and acquire a certain degree of thickness. During this operation, however, you must take care to blow, now and then, into the tube, in order to retain a hollow space in the midst of the little mass of glass, and to hinder the bore of the tube from being closed up. When you have thus, at the expense of the length of the tube, accumulated at its extremity a quantity of glass sufficient to produce a bulb, you have

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nothing more to do than to heat the matter till it is raised to a temperature marked by a *reddish white* colour, and then to expand it by blowing.

Instead of accumulating the glass thus, it is more expedient to blow on the tube a series of little bulbs close to one another, and then, by heating the intervals, and blowing, to unite these little bulbs into a large one of convenient dimensions.

I have already observed, and I repeat here, that it is indispensably necessary to hold the glass *out* of the flame during the act of blowing. This is the only means of maintaining uniformity of temperature in the whole softened parts of the tube, without which it is impossible to produce bulbs with sides of equal thickness.

When you desire to form a bulb at the extremity of a capillary tube, that is to say, of a tube that has a bore of very small diameter, such as the tubes which are commonly employed to form thermometers, it would be improper to blow it with the mouth; were you to do so, the vapour which would be introduced, having a great affinity for the glass, would soon obstruct the little canal, and present to the passage of the air a resistance, which, with the tubes of smallest interior diameter, would often be insurmountable. But, even when the tubes you employ have not so very small an internal diameter, you should still take care to avoid blowing with the mouth; because the introduction of moisture always injures fine instruments, and it is impossible to dry the interior of a capillary tube when once it has become wet. It is better to make use of a bottle of Indian rubber, which can be fixed on the open end of the tube by means of a cork with a hole bored through it. You press the bottle in the hand, taking care to hold the tube vertically, with the hot part *upwards*; if you were not to take this precaution, the bulb would be turned on one side, or would exhibit the form of a pear, because it is impossible, in this case, to give to the mass in fusion that rotatory motion which is necessary, when the tube is held horizontally, to the production of a globe perfectly spherical in its form, and with sides of equal thickness.

Whenever you blow into a tube you should keep your eye fixed on the dilating bulb, in order to be able to arrest the passage of air at the proper moment. If you were not to attend to this, you would run the risk of giving to the bulb too great an extension, by which the sides would be rendered so thin that it would be liable to be broken by the touch of the lightest bodies. This is the reason that, when you desire to obtain a large bulb, it is necessary to thicken the extremity of the tube, or to combine many small bulbs in one, that it may possess more solidity.

In general, when you blow a bulb with the mouth, it is better to introduce the air a little at a time, forcing in the small portions very rapidly one after the other, rather than to attempt to produce the whole expansion of the bulb at once; you are then

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more certain of being able to arrest the blowing at the proper time.

When you desire to produce a moderate expansion, either at the extremity or in any other part of a tube, you are enabled easily to effect it by the following process, which is founded on the property possessed by all bodies, and especially by fluids, of expanding when heated; a property which characterises air in a very high degree. After having sealed one end of the tube, and drawn out the other, allow it to become cold, in order that it may be quite filled with air; close the end which has been drawn out, and prevent the air within the tube from communicating with that at its exterior; then gradually heat the part which you desire to have expanded, by turning it gently in the flame of a lamp. In a short time the softened matter is acted on by the tension of the air which is enclosed and heated in the interior of the tube; the glass expands, and produces a bulb or swelling more or less extensive, according as you expose the glass to a greater or lesser degree of heat.

To blow a bulb in the middle of a tube, it is sufficient to seal it at one of its extremities, to heat the part that you wish to inflate, and when it is at a *cherry red* heat, to blow in the tube, which must be held horizontally and turned with both hands, of which, for the sake of greater facility, the left may be held above and the right below.

If the bulb is to be large, the matter must previously be thickened or accumulated, or, instead of that, a series of small bulbs be first produced, and these subsequently be blown into a single larger bulb, as I have already mentioned.

You make choice of a tube which is not capillary, but of a sufficient diameter, very cylindrical, with equal sides, and tolerably substantial: it may generally be from the twentieth to the twelfth of an inch thick in the glass. You soften two zones in this tube, more or less near to each other, according to the bulk you desire to give to the bulb, and you draw out the melted part in points. The talent consists in *well centering*—that is to say, in drawing out the melted tube in such a manner that the thin parts or points shall be situated exactly in the prolongation of the axis of the little portion of the original tube remaining between them. This operation is technically termed drawing *a cylinder between two points*. You cut these points at some distance from the central or thick part, and seal one end; you next completely soften the little thick tube and expand it into a bulb, by blowing with the precautions which have already been described. You must keep the glass in continual motion, if you desire to be successful in this experiment. Much rapidity of movement, and at the same time lightness of touch, are requisite in the operation here described. It is termed *blowing a bulb between two points*.

To obtain a *round* bulb, you should hold the tube horizontally; to obtain a *flattened* bulb, you should hold it perpendicu-

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larly, with the fused extremity turned above; to obtain a *pear shaped* bulb, you should hold the fused extremity downwards.

When you are working upon a bulb between two points, or in the middle of a tube, you should hold the tube horizontally, in the ordinary manner; but you are to push the softened portion together, or to draw it out, according as you desire to produce a ridge or a prolongation.

For some instruments, the tubes of which must be small, it is necessary to blow the bulbs separately, and then to solder them to the requisite adjuncts. The reason of this is, that it would be too difficult to produce, from a very small tube, a bulb of sufficient size and solidity to answer the intended purpose.

The following figure affords an example of this sort of work.

c is a bulb blown from a large tube; *a b*, are two narrow tubes, soldered to the bulb *c* at two opposite *drawn out* points *e* and *i*. See the article "Soldering." I have shown the full size of a bulb of this description, at page 227.

When you are at liberty to choose the point from which you are to blow, you should prefer, 1st, that where the moisture of the breath can be the least prejudicial to the instrument which is to be made; 2dly, that which brings the part which is to be expanded nearest to your eye; 3dly, that which presents the fewest difficulties in the execution. When bulbs are to be formed in complicated apparatus, it is good to reflect a little on the best means of effecting the object. It is easy to understand that contrivances which may appear very simple on paper, present difficulties in the practical execution which often call for considerable management.

8.—Piercing.

You first seal the tube at one extremity, and then direct the point of the flame on the part which you desire to pierce. When the tube has acquired a *reddish white* heat, you suddenly remove it from the flame, and forcibly blow into it. The softened portion of the tube gives way before the pressure of the air, and bursts into a hole. You expose the tube again to the flame, and border the edges of the hole.

It is scarcely necessary to observe, that, if it be a sealed extremity which you desire to pierce, it is necessary to turn the tube between the fingers while in the fire; but if, on the contrary, you desire to pierce a hole in the side of a tube, you should keep the glass in a fixed position, and direct the jet upon a single point.

If the side of the tube is thin, you may dispense with blowing. The tube is sealed and allowed to cool; then, accurately closing the open extremity with the finger, or a little wax, you

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expose to the jet the part which you desire to have pierced. When the glass is sufficiently softened, the air enclosed in the tube being expanded by the heat, and not finding at the softened part a sufficient resistance, bursts through the tube, and thus pierces a hole.

You may generally dispense with the sealing of the tube, by closing the ends with wax, or with the fingers.

There is still another method of performing this operation, which is very expeditious, and constantly succeeds with objects which have thin sides. You raise to a *reddish white* heat a little cylinder of glass, of the diameter of the hole that you desire to make, and you instantly apply it to the tube or globe, to which it will strongly adhere. You allow the whole to cool, and then give the auxiliary cylinder a sharp slight knock; the little cylinder drops off, and carries with it a portion of the tube to which it had adhered. On presenting the hole to a slight degree of heat, you remove the sharpness of its edges.

When you wish to pierce a tube laterally, for the purpose of joining to it another tube, it is always best to pierce it by blowing many times, and only a little at a time, and with that view, to soften the glass but moderately. By this means the tube preserves more thickness, and is in a better state to support the subsequent operation of soldering.

There are circumstances in which you can pierce tubes by forcibly sucking the air out of them; and this method sometimes presents advantages that can be turned to good account. Finally, the orifices which are produced by cutting off the lateral point of a tube drawn out at the side, page 252, may also be reckoned as an operation belonging to this article.

9.—Bending.

If the tube is narrow, and the sides are pretty thick, this operation presents no difficulty. You heat the tube, but not too much, lest it become deformed; a *reddish brown* heat is sufficient, for at that temperature it gives way to the slightest effort you make to bend it. You should, as much as possible, avoid making the bend too abrupt. For this purpose, you heat a zone of one or two inches in extent at once, by moving the tube backwards and forwards in the flame, and you take care to bend it very gradually.

But if the tube is large, or its sides are thin, and you bend it without proper precautions, the force you employ entirely destroys its cylindrical form, and the bent part exhibits nothing but a double flattening,—a canal, more or less compressed. To avoid this deformity it is necessary, first, to seal the tube at one extremity, and then, while giving it a certain curvature, to blow cautiously by the other extremity, which for convenience sake should previously be drawn out. When tubes have been deformed by bad bending, as above described, you may, by following this method, correct the fault; that is to say, upon sealing one ex-

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tremity of the deformed tube, heating the flattened part, and blowing into the other extremity, you can, with care, reproduce the round form.

That a curvature may be well made, it is in general necessary that the side of the tube which is to form the concave part be sufficiently softened by heat to sink of itself equally in every part during the operation, while the other side be only softened to such a degree as to enable it to give way under the force applied to bend it. On this account, after having softened in a *cherry red heat* one side of the tube, you should turn the other side, which is to form the exterior of the curvature, towards you, and then, exposing it to the point of the jet, you should bend the tube immediately upon its beginning to sink under the heat.

Many glass tubes can be conveniently bent after being heated over the large spirit lamp, (page 19). Very large and thick glass tubes are best softened, for bending, by being placed in a long charcoal fire, made between bricks ranged lengthwise upon a hearth.

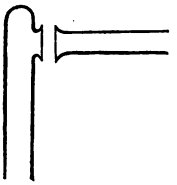
10.—Soldering.

If the tubes which you propose to solder are of small diameter, pretty equal in size, and have thick sides, it is sufficient, before joining them together, to widen them equally at their extremities, by agitating a metallic rod within them when soft.

But if they have thin sides, or are of large diameter, the bringing of their sides into juxta-position is very difficult, and the method of soldering just indicated becomes insufficient. In this case you are obliged to seal, and subsequently to pierce, the two ends which you desire to join. The disposition which this operation gives to their sides very much facilitates the soldering.

Finally, when the tubes are of a very different diameter, you must draw out the extremity of the larger, and cut it where the part drawn out corresponds in diameter to the tube to which it is to be joined.

For lateral solderings you must dispose the tubes in such a manner that the sides of the orifices which you desire to join together coincide with each other completely, as represented in the annexed figure. The upright tube is drawn out latterly, pierced, and bordered, and the end of the other tube is bordered to correspond with it in size.



When the holes are well prepared, you heat at the same time the two parts that are to be soldered together, and join them at the moment when they enter into fusion. You must push them slightly together, and continue to heat successively all their points of contact; whereupon the two tubes soon unite perfectly. As it is almost always necessary, when you desire the soldering to be neatly done, or the joint to be

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imperceptible, to terminate the operation by blowing, it is proper to prepare the extreme ends of the tubes before hand. That end of the tube by which you intend to blow should be carefully drawn out, provided it be so large as to render drawing out necessary; and the other end of the tube, if large, should be closed with wax, or if small, should be sealed at the lamp. When the points of junction are perfectly softened, and completely incorporated with each other, you introduce a little air into the tube, which produces a swelling at the joint. As soon as this has taken place, you must gently pull the two ends of the joined tube in different directions, by which means the swelled portion at the joint is brought down to the size of the other part of the tube, so that the whole surface becomes continuous. The soldering is then finished.

To solder a bulb or a cylinder between two points, to the extremity of a capillary tube, you cut and seal one of the points at a short distance from the bulb, and at the moment when this extremity is in fusion you pierce it by blowing strongly at the other extremity. By this means the opening of the reservoir is terminated by edges very much widened, which facilitates considerably its being brought into juxta-position with the little tube. In order that the ends of the two tubes may be well incorporated the one with the other, you should keep the soldered joint for some time in the flame, and ought to blow in the tube, push the ends together and draw them asunder, until the protuberance is no longer perceptible.—See the article Blowing.

If, after having joined two tubes, it should be found that there still exists an opening too considerable to be closed by simply pushing the two tubes upon one another, you can close such an opening by means of a morsel of glass, applied by presenting the fused end of an auxiliary tube.

You should avoid soldering together two different species of glass—for example, a tube of hard glass with a tube of flint glass; because these two species of glass experience a different degree of contraction upon cooling, and, if joined together while in a fused state, are so violently pulled from one another as they become cool, that the cohesion of the point of soldering is infallibly overcome, and the tube breaks. You ought also, for a similar reason, to take care not to accumulate a greater mass of glass in one place than another.

If the first operation has not been sufficient to complete the soldering, the tube must be again presented to the flame, and again pushed together at the joint, or drawn asunder, or blown into, according as it may appear to be necessary. In all cases the soldering is not truly solid, but inasmuch as the two masses of glass are well incorporated together, and present a surface continuous in all points.

The small blowpipe, (page 238) is that which is to be employed in preference to the larger flame, when you desire to

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effect a good joining: it is sufficient to proportion the size of the flame to the object you wish to execute.

THE LABORATORY.

The notion, that a laboratory fitted up with furnaces and expensive and complicated instruments, is an absolute requisite for the proper performance of chemical experiments, is exceedingly erroneous. In fact, the truth is quite opposed to this opinion. "For general and ordinary chemical purposes," says Dr Henry, "and even for the prosecution of new and important inquiries, very simple means are sufficient: some of the most interesting facts of the science may be exhibited and ascertained with the aid merely of Florence flasks, of common phials, and of wine glasses. In converting these to the purposes of apparatus, a considerable saving of expense will accrue to the experimentalist; and he will avoid the encumbrance of various instruments, the value of which consists in show rather than real utility." It is a curious and instructive fact, that some of the most important discoveries in chemistry were made by persons who, either from choice, or motives of economy, used utensils of the very simplest character. The laboratory of the great Priestley cost a mere trifle; and it is well known how savingly Franklin went to work. The student will beware of procuring the large and showy apparatus which strike his eye from the lecturer's table, for they are useless to him.

Method, order, and cleanliness, are essentially necessary in a chemical laboratory. Every vessel and utensil ought to be well cleansed as often as it is used, and put again into its place; labels ought to be put upon all glasses and boxes containing preparations. Apparatus and preparations should be kept on shelves, or in drawers, where they can be readily found when wanted. The care of cleansing and arranging vessels, which seems to be trifling, is very fatiguing and tedious; but it is also very important, though frequently little observed. When a person is keenly engaged, experiments succeed each other quickly; some seem nearly to decide the matter, and others suggest new ideas; the experimentalist cannot but proceed to them immediately, and he is led to pass from one to another; he thinks he shall easily know again the products of the first experiments, and therefore does not take time to put them in order; he prosecutes with eagerness the experiments which he has last thought of; and, in the meantime, the vessels employed, the glasses, and bottles, and products, so accumulate, that he can no longer distinguish them; or at least he is uncertain con-

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cerning some particular product. This evil is increased, if a new series of operations succeed, and occupy the laboratory, or if he be obliged to quit it; for in these cases, every thing goes into confusion. Thence it frequently happens, that the chemist loses the fruits of much labour, and is obliged to throw away almost all the products of his experiments.

When new researches and inquiries are made, the products of all the operations ought to be kept a long time, distinctly labelled and registered; for these things, when kept some time, frequently present phenomena that were not at all anticipated. Many fine discoveries in chemistry have been made in this manner; and many have certainly been lost, by throwing away too hastily, or neglecting the products of experiment.

Your work table (of which more anon) should be strong and level, and placed fronting a window in a room free from dust and disturbance, and where there are no children. Most chemical preparations are poisonous or hurtful; and all should be carefully kept out of the reach of those who might unwittingly do themselves harm.

Beware of the droppings of bottles! Remember that acids and alcalies can either alter the colour of clothes and furniture or burn holes in them. Take care how you pour liquors from bottles, and never let any run down the outside of the bottle. I have told you how to prevent it in the article on *decantation*. You should, however, always have some tow or old rags at hand, to wipe up any thing that is spilled accidentally.

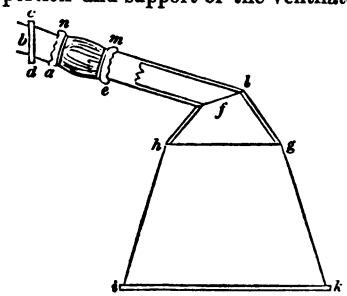
Beware also of the mischief that may arise from the breaking of vessels containing large masses of liquid. When distillations are undertaken, or operations of any kind requiring much liquid are carried on, there should be no carpets or good furniture in the room, or the apparatus should be placed over deep pans, as will be described in a subsequent article upon Distillation.

The sort of experiments most proper for *the parlour table* are those made with the blowpipe, or with the small vessels which are adapted to the lamp furnace. Experimenting in miniature can be carried on to a great extent. There is scarcely an operation described in the preceding pages capable of producing results unattainable by an apparatus of blowpipes and test tubes wrought with ease and safety over a tea tray or a large earthenware dish. I would therefore recommend the young student to make his experiments on the smallest scale. It is what the most eminent chemists are doing more and more every day. The cleverest philosopher is he who can effect a given object by the easiest means.

I recommend the young student to buy only the most indispensable articles at first, and to increase his stock of apparatus by buying other articles when he wants them. Most people fall into the error of buying a great quantity of apparatus for which they have no use, particularly when they begin with the purchase of apparatus only intended for the lecture table.

The two most essential requisites to be provided in the conversion of a *parlour* or a *school room* into a *laboratory*, are VENTILATION and a proper WORK TABLE, on both of which subjects I shall say a few words.

VENTILATION.—It is extremely convenient to have the power of performing in a comfortable room a variety of chemical operations, which are necessarily attended by the production of smoke and suffocating vapours, without being at the same time annoyed by those vapours. To gain this object, BERZELIUS recommends the use of a moveable chimney, or ventilator, of the following construction. An opening is broken into a chimney, and a black iron pipe, six inches in diameter, is fixed into the hole so produced. The length of this pipe may be 18 or 24 inches. Across the middle of it, there must be a damper, fixed in a long flat box, in such a manner that the pipe may either be left wide open, or be more or less closed, as occasion requires. Where a hole cannot be broken into a chimney, the pipe may be passed through a wall, or through a window, and be connected outside with a few feet of perpendicular pipe, to create a draught; or it may go straight upwards through the roof of the apartment, if local circumstances render that method preferable. The iron pipe, fixed in any of these ways, forms the upper portion and support of the ventilator, which is represented in the annexed figure. *b a n*, is the end of the iron pipe that goes into the chimney. *c d*, is the damper and its box. *e m l f*, is a tube of paper (or pasteboard) strengthened by two sticks, *m l*, and *c f*, to which it is nailed. *l f g h*, is a circular paper funnel, connected with the paper pipe, and strengthened like it by two sticks, *f h*, and *l g*.



This funnel should be nearly three feet wide at the bottom, and about eight inches deep from the end of the paper pipe. *g k i h*, is a circular hood, or canopy, of wax cloth, (waterproof cloth would answer better, but painted canvass would be cheapest,) measuring five or six feet in diameter at the lower end, where it is stretched by a strong iron wire, and sewed above to the paper funnel at *h g*. The whole apparatus is fastened to the iron tube, *b a n*, by a flexible connector of wax cloth, (waterproof cloth,) *a n m e*, which is fastened at one end to the iron pipe, and at the other to the paper pipe. A ring is fastened at the top of the funnel *l*, from which a cord passes upwards, over a pulley fixed to the roof, and is connected with a leaden counterpoise and hand pull, in a corner of the room.

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By this means the canopy, when not in use, can be pulled up out of the way.

Under a ventilator of this description, you place a work table with its lamp, and perform the various operations which produce steam, smoke, or deleterious gases, such as evaporation, boiling, solution in acids, glass blowing, testing with sulphuretted hydrogen, &c. Independent of the comfort which such a ventilator gives, it is of importance, as tending to prevent the unhealthy effects produced on the body when such vapours as I have alluded to are permitted to remain in a room and to be inhaled. It is in all cases advisable to give an apparatus of this kind a coat of siliceous varnish, to prevent its catching fire from sparks and burning with flame. Siliceous varnish, adapted for this purpose, is not an expensive article.

Work Table.—Although any sort of table can be used to make experiments upon, it may not be amiss to state what sort of table answers best. As the breaking of glass vessels and other accidents cause the spilling of chemical solutions which corrode wood, and destroy colours and varnishes, the table of the chemists commonly has a very dirty appearance. This, however, should be prevented as much as possible. It is unpleasant to see, and its toleration encourages a habit of inattention to dirt which is injurious to successful experimenting. No teacher should suffer anything dirty to be used or to be seen in use by his pupils. Dr Wollaston was particularly nice in his attention to the state of his apparatus; Mitscherlich works upon tables of polished wood, having sunk trays of glazed porcelain; and Berzelius instructs us to inlay our table with slabs of pottery (glazed Dutch tiles, which however are not to be procured in Scotland.) He says that the tiles should be laid close together and cemented with lintseed oil varnish mixed with oxide of zinc or with sulphate of barytes.

I have been trying to manufacture glazed stoneware trays or work tables for chemists, but have been hitherto disappointed, in consequence of the difficulty experienced in firing large plates of stoneware, without injury to their flat form. I shall probably, however, yet succeed in making some useful article of that description, as my experiments are still going forwards. In the meantime I may mention that a table with a cast iron, or lead top, answers very well for most purposes. Such a table, placed under a ventilator in this manner, at once converts a common dwelling room into a convenient chemical laboratory. When, however, you are obliged to work at a good table, it is prudent to employ an old tea tray, a large flat tray of sheet lead, a stone pan, or the small flat glazed stone trays described in the Appendix. These may save the mahogany from destruction.

Besides the work table and a contrivance for carrying off un-

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pleasant vapours, there are a few other requisites necessary to be had in *every laboratory*, however small it may be, and on which, for that reason, I shall say a few words.

An abundant supply of *water* is necessary, and it is very desirable that a sink and cistern should be at hand; but if these cannot be provided, a stone greybeard, holding at least a gallon, with a stop cock fixed into the side of it near the bottom, should be fixed up breast high for the supply of water, and below it there should be a large pan or another greybeard, with a large funnel, for the reception of dirty water.

There should be a supply of *drawers* and *shelves*, of various sizes, to hold bottles, jars, flasks, work tools, and all sorts of apparatus, in good order, ready for use. If the room devoted to be used as a laboratory, contains *cupboards*, they may be fitted up for the reception of apparatus; if not, the work table may be divided into two parts, and the one half be fitted up with drawers, and the other be formed into a cupboard. Or, finally, both drawers and shelves may be affixed to the wall, care being taken, where this is done in a dwelling house, to lock up, or to place all injurious or fragile things beyond the reach of children.

A candle or small oil lamp, and a supply of lucifer matches, or a hydrogen lamp, for providing a light; and a note book, with pen and ink, for journalising the experiments which are performed, are also indispensable.

As to the apparatus necessary to be provided, the quantity and variety must depend upon the course of operations which is to be undertaken, and upon the means or liberality of the operator. In the lists of apparatus and preparations given in the Appendix, I notice what will be required in a place where experiments in various branches of chemistry are to be carried on. It must necessarily be left to the taste and judgment of every reader to procure what appears to be most adapted to his particular wants or intentions. I have endeavoured to assist him in selecting the different articles of apparatus, by giving him all the information in my power respecting their *value*, both *philosophical* and *pecuniary*.

I proceed now to describe a few general operations, chiefly relative to the preparation, alteration, and repair of apparatus, which may not unfitly close this article.

Cork Boring and Cutting.—As corks of various sizes are frequently in demand, you should be provided with two or three large pieces (half a square foot) of cork of the best quality, (soft, free from holes and from hard lumps,) and of different thicknesses, from which to cut what you may require. The tools which you will need for shaping corks for various purposes are as follows: a knitting needle, a small round file, a large round file, a flat file, a press, a set of cork borers, and a knife.

Knife.—A common shoemaker's knife, with a sandstone for

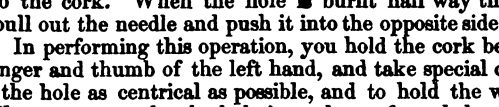
sharpening it upon. With this you cut the piece of cork as nearly into the shape you wish it as you can.

Flat File.—With this you file the cork into the desired shape. The teeth of the file must not be too fine, but rather of the rasp order. It is easier to file a cork than to cut it into a given shape.

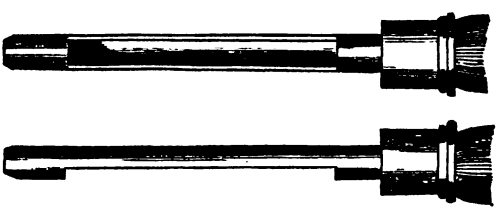
Cork Press.—Two short strong pieces of hard wood, connected by a hinge at one end, something like a pair of nut crackers, with a series of corresponding semi-circular grooves, of different sizes, in the faces that meet together, like the cavity *a*, page 40. The use of this press is to squeeze a round cork till it is softened and made elastic.

Knitting needle.—When you want to make a small hole through a cork, you heat the knitting needle red hot, and push it into the cork. When the hole is burnt half way through, you pull out the needle and push it into the opposite side of the cork. In performing this operation, you hold the cork between the finger and thumb of the left hand, and take special care to burn the hole as centrical as possible, and to hold the wire so steadily as not to make the hole irregular or funnel shaped.

Round Files.—When a hole is once burnt through a cork, it can be enlarged to any extent by means of round files, with rough teeth (fine rasps), of which it is necessary to have a small one (three inch), and a large one (six inch). It requires considerable care and practice to file a hole cylindrical from end to end. You succeed best by holding the cork between the left finger and thumb, and turning it gradually round about, while the file is managed by the right hand, and applied at the two ends of the cork alternately. When the teeth of the file become filled up with cork and dust, they can be cleared by soaking the file in a ley of lime and potash.



Danger's Cork Borer.—The cut represents a front and side view of an instrument for boring or cutting holes in corks,



devised by M. Danger, of Paris. It consists of a hardened steel tube, one end of which is fixed in a handle, and the other end ground to a cutting edge. The cork to be bored is held in the left hand, and the borer, previously oiled, is held in the right

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hand, and pressed through the cork with a twisting motion, after the manner of a gimlet or cork screw, by which means a cylindrical piece is neatly cut out of the cork, and a smooth cylindrical hole produced. There is an opening on the side of the borer made to permit of the extraction of the cylinders of cork from it. As each borer only cuts one size of hole, it is necessary to be provided with several sizes, to make perforations for tubes of different diameters. The price of steel borers of this description, with wooden handles, in sizes from $\frac{1}{8}$ inch to $\frac{1}{3}$ inch diameter, is 1s. 3d. each.

Mohr's Cork Borer.—An instrument for boring corks which answers better than Danger's, has been recently (*Annalen der Pharmacie, Januar* 1837,) described by Dr Mohr of Coblentz.

It is a tube of tin plate, six inches long, bent as cylindrical as possible, and soldered flat where the edges meet at the side. There should be a set of 12 tubes, passing within one another, like the drawers of a telescope, the largest of them being $\frac{3}{4}$ inch wide. A wire ring is soldered round one end of each tube, and the other end is sharpened to a cutting edge by a half round file, the flat side of which acts upon the outside of the tube, and the round part upon the inside. The 12 tubes are marked by the file on their rings, and a set of holes are cut in the side of a tin plate to serve as a guage for the width of the tin tubes, each hole being numbered to correspond with the tube that fits it. The use of the guage is to determine the thickness of the glass tubes for which holes are to be bored, and to show which cutting tube should be used for the purpose. As the tin tubes are of like thickness throughout, the piece of the cork which is cut out to form the hole, passes easily up the cutting tube in the form of a solid cork cylinder, fit for a stopper.

The operation of boring is very easy. The borer is held in the right hand, and the cork is applied with the left hand to the sharp edge of the borer, where it is held steady, while the borer is slowly turned round, or else the cork and borer are turned round in opposite directions. Very little pressure is used, the cutting being performed by an operation similar to that of sawing. The forefinger of the left hand is applied to that part of the cork where the borer is to come out, and when the approach of the borer is felt, the finger is removed, another cork is applied in its place, and the turning of the borer is renewed with a slight pressure. By this means the cork is cut out with a neat round end. The orifice made by this operation is perfectly cylindrical and smooth on the surface. It is necessary, for each operation, to moisten the cutting tube both inside and outside with a little sweet oil. Each borer may be provided with a hollow wooden handle, which makes the use of it more convenient.

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As I have not been able to get tin plate tubes made of very small diameters, nor made of any size without an overlap of the metal at the line of junction, which offers an impediment to the boring, I have been using *thin brass tubes* for cork boring, with great advantage. These are easily procured, and in such variety, that from the diameter of $\frac{1}{8}$ inch up to that of $1\frac{1}{4}$ inch, I have obtained more than twenty varieties, with any of which smooth cylindrical holes can be cut in cork, by the extraction of smooth cylindrical pieces of cork, which answer for stoppers. The brass tubes are sharpened at one end, internally by a small round file, and externally by a flat file, in the manner described above, and they are oiled previous to use. After every operation, the cork cylinder must be pushed out of the borer, by means of a thick iron wire. As often as the borer gets dull on the edge, it must be sharpened anew by the files. If the borer happens to get squeezed and lose its cylindrical form, it must be hammered into shape on the spike of an anvil (p. 273).

Hitherto I have only succeeded in procuring tubes of four inches in length, which is too short for convenient holding, excepting for the tubes of less than half an inch in diameter. These, however, are the most useful kinds, since it is easier to enlarge a hole by the file when once it is made, than it is to make it in the first instance. And for making small holes, the narrow cork borers are incomparably better than the red hot knitting needle. The price of these small sized brass borers is very low, a set of 6 tubes costing only 1s. I expect soon to succeed in procuring the larger sizes, 6 inches in length, and perhaps assorted to the width of 2 inches, with a tube of which diameter I find it possible to cut cylindrical corks for closing large tubes, such as the condenser, page 201.

It is not necessary to procure all the various sizes of small boring tubes, which I have said it is *possible* to procure; because I find, that with even that great assortment, it is impossible to dispense with either the flat file or the round one, so variable are the sizes of glass tubes and of flask mouths. It is however useful to have a pretty good assortment of borers, in order that when you have to fit a tube to a flask, you may have a *good chance* of finding *one* borer that can cut a cork to fit the flask, and *another* that can make a hole to fit the tube. When this can be done so as to dispense with the files, *it saves a great deal of time;* and as the cost of the borers is so trifling, this is a consideration of importance.

I have also endeavoured, though yet without success, to procure cork borers of the necessary variety of diameters, in the form of *thin steel cylinders*, which would be more useful and durable than either tin plate or brass.

Since the foregoing article was written, I have received from the manufacturer a set of *twelve brass cork borers, six inches in length*, perfectly smooth in the bore, and of the following dia-

meters: 2, 3, 4, 5, 6, 7, 8, 10, 12, 14, 16, and 20 SIXTEENTHS of an inch. With this set of borers, and a round and flat file to sharpen them, and a small and large round file for occasional slight enlargement of the holes which they cut, it is possible to prepare in a few minutes cork cylinders, or cylindrical holes, of any size between $\frac{1}{8}$ inch and $1\frac{1}{4}$ inch; so that the operation of adapting tubes to flasks, which was formerly so troublesome and so destructive of time, is now rendered so very facile and certain as to do away with the necessity of applying cements to corks in at least five cases out of six.

The price of this set of twelve brass cork borers, is 3s.—The price of a set of the seven smallest sizes, $\frac{1}{8}$ inch to $\frac{1}{2}$ inch, is 1s. 6d.

ELASTIC TUBE MAKING.—I have referred, at page 225, to the use of elastic tubes of caoutchouc in connecting together the several parts of a complex glass apparatus. A great many cases of this sort will have to be referred to in the subsequent pages of this work, and as these tubes have frequently to be made as well as used by the experimenter, it is proper to describe the *method* of making them. The material of which they are made is sheet Indian rubber of about the twelfth of an inch in thickness, which may be bought in Glasgow in pieces of 25 square inches for 6d., and of 100 square inches for 1s. 6d.

Take a piece of the sheet rubber, 1 or $1\frac{1}{2}$ inches long, and a little more than three times as wide as you intend the tube to be. Take a glass rod rather smaller than the intended caoutchouc tube, fold a slip of paper round the glass rod, and over it the piece of caoutchouc, previously softened by warming before the fire. Fold the two edges together, and cut off the double projecting edges by a pair of scissors, so as to produce two parallel straight edges. Put the two clean surfaces thus produced face to face, being careful not to let the fingers or any thing else touch them. Press the two faces together by the thumb nails, and finally press the seam from end to end with the flat part of the thumb nail. The junction is then effected, and the tube complete. But if the fingers or any dirt is allowed to touch the clean cut surfaces of the rubber, they cannot be made to unite by pressure. After you have withdrawn the glass rod and the slip of paper from the rubber tube, you are to smear its inner surface with flour or fine ashes, to prevent the subsequent sticking together of its sides, which is otherwise liable to take place.

To form a conical elastic tube for connecting glass necks of unequal size, you must fold the rubber upon a retort neck, or a conical piece of wood, such as the stick used in putting wicks into lamps. A piece of paper previously adjusted to the cone, and cut to the proper length, serves as a pattern by which to cut out the necessary slip of rubber from the sheet without waste.

A caoutchouc tube answers best when its two ends are as near

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as possible of the same size as the two glass tubes which it is to connect. It is put over them with a little stretching, and binds them sufficiently tight for many purposes without tying. But when tying is necessary, it is best done with silk cord, which is less apt than common twine to cut through the caoutchouc tube. The connected glass tubes need never be more than a quarter of an inch asunder, so that very short caoutchouc tubes are sufficient for the purpose.

These tubes are destroyed by a heat exceeding 170° F., and consequently cannot suffer the passage of steam. They are acted upon by fat and by volatile oils, turpentine, &c.; and also by strong nitric and sulphuric acid, and slightly by chlorine. They permit the passage of all other gases.

Preparation of Sheet Rubber from Small Bottles.—Where small bottles of Indian rubber are more easily procured than sheet rubber, it may be useful to know how they can be expanded so as to answer the same purpose. Place a sound rubber bottle at the bottom of a beaker glass that nearly fits it. Pour into the glass as much sulphuric ether as rises to the neck of the bottle but does not cover the neck. The ether must be quite free from alcohol. Bind the mouth of the glass air tight with a piece of wet bladder, and set it in a cool place for 6 hours, if the bottle is small and thin, or for 12 or 24 hours according to the greater size of the bottle. The steeping should continue till the rubber ceases to be elastic, but not till it becomes so soft as to stick strongly to the fingers. When the bottle is sufficiently soaked, put a little powdered starch into it, and shake it about. Then insert the neck of a stop cock into its mouth, using a cork when the mouth of the bottle is too large to fit the stop cock. Fold a bit of leather twice round the neck of the bottle over the stop cock, and tie it on with a string. When the rubber bottle is thus fixed air tight upon the stop cock, you open the latter and blow a little air into the bottle, then you close the stop cock and let it rest a while, after which you open it again and blow in a little more air. And thus you continue to blow air into it, a little at a time, until the bottle is properly expanded, which it is when the substance of the expanded ball is about one twentieth of an inch in thickness.—*Mohr.*

Glass Cutting and Grinding.—It is frequently necessary, in the laboratory, to resort to glass grinding, particularly when you reside at any distance from professional glass cutters and instrument makers. The use of glass grinding is to fit stoppers to bottles, to adjust flat glass plates to the mouths of funnels or jars, and to adapt retorts to receivers, and tubes to gas bottles, in such a manner as to dispense with cementing.

Unground stoppers can scarcely be fitted to unground bottles, without the use of a turning lathe. A copper cone is fixed in the lathe, and anointed with a mixture of emery and oil, and the bottle, held in the right hand, is forced upon the revolving

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copper cone. For cutting the stopper, a revolving hollow copper cone is employed in the same manner. The copper tools must be only very slightly conical. When the stopper is thus made to correspond in a rather rough way to the bottle, it is for the purposes of *sale* commonly considered to be finished, but for *use* in chemical operations the adjustment requires to be made more perfect. This is managed by holding the bottle and stopper in your two hands, anointing the latter with emery and oil, and working the two together till they fit properly, that is to say, till they turn round easily, and are easy to put close together and to separate. It is necessary to have emery of three different degrees of fineness, and to proceed gradually from the coarse to the fine, taking care to wash off the paste of coarse emery from the vessels before you apply the finer sort.

Glass stoppers sometimes stick so tight into their bottles, that they cannot be pulled out in the ordinary way. The best way of removing them is to hold the neck of the bottle horizontally over the flame of a small spirit lamp, taking care to turn round the bottle continually, by which means the whole neck of the bottle—the cylinder which embraces the fixed stopper, is suddenly heated and expanded. The stopper then commonly loosens and may be pulled out. But when it happens to be cemented in its place by saline matter, it is necessary to invert the flask in a cup of water, and allow the salt to dissolve. Sometimes, a drop of sweet oil put round the stopper, and allowed to rest there a few hours, while the bottle is placed in a warm situation, will soak in between the neck and stopper, and cause the latter to loosen. Frequently, a piece of thin cord, tied round the stopper, affords a handle by which the stopper can be extracted by a steady pull. And in other cases, a few slight blows with a block of wood (never with metal), applied to each side of the stopper, will loosen it. When, however, caustic alcali has got between the ground faces of a neck and stopper, and the latter is fixed, there is no hope to be entertained of its extraction. The cutting off of the neck of the bottle is then the only remedy.

For grinding flat plates of glass and the edges of vessels, it is necessary to be provided with three discs of sheet lead, or copper, eight or ten inches in diameter, upon which the glass is ground with a mixture of emery and water. Each plate is employed with emery of a different degree of fineness; the same powder is always used with the same plate; and the glass is carefully washed from one before it is applied to the other. If this is not attended to, the work becomes full of scratches and ruts.

Lapidary Work.—The cutting of stone is effected in the same manner as the cutting of glass. It comes to be necessary in some cases of distillation where the stoppers of flasks, which require to be provided with gas delivering tubes and funnels, cannot be made of cork. The substances used in such cases are

serpentine, talc, meerschaum, graphite, or pieces of black lead crucibles. Many of these substances can, however, be worked by means of a knife and file into the desired forms.

A more important, and a stricter example of lapidary work is afforded in the cutting and polishing of minerals, many of which can only be properly examined as to their apparent construction and state of mechanical intermixture, after being cut and polished. The mineral is for this purpose broken to an even surface, and is ground upon lead plates, with water and emery, of which at least five different sorts, in respect of fineness, must be provided. In every case of passing from a coarse emery to a finer sort, the mineral must be carefully washed from particles of powder, which otherwise would produce scratches. Finally, the mineral is ground with very fine emery prepared by washing, (pages 5, 6), and is polished upon a lead plate with tripoli or washed red oxide of iron, (jeweller's rouge). This operation requires more patience than skill, and the art is readily acquired.

Of the different sorts of emery, the coarser are prepared by pounding and sifting; the finer by mixing the powdered emery in water, and pouring off the liquid after ½ minute's subsidence; and again after 2 minutes' subsidence, and so on; by which means a variety of different sediments are obtained.

The Lapidary's wheel is a dise of copper or lead which is made to revolve horizontally. The object to be cut is held steadily upon it. Slices of a mineral are cut by a revolving thin disc of copper, having a rough edge anointed with a paste of emery, or of diamond powder. The mineral to be sliced is pressed steadily against the edge of this revolving disc.

Working of Metals.—There are several small tools of so much use in the repair or alteration of the metallic parts of chemical apparatus, that I may as well give them a short notice among the other odd matters which make up this article. Schoolmasters and persons residing in the country, where instrument makers do not abound, cannot dispense with the use of these tools, unless they propose to give up the pursuit of the science, or to carry on their researches and demonstrations under needless difficulties.

Strong Shears. Useful in cutting sheet metals into shape.

A Small Vice, which can be screwed to the edge of a table when it is to be used. It serves to hold wires and other substances, when being filed or otherwise wrought.

A Hand Vice, which is a vice fastened to an iron rod, to be held in the hand when used, serves to secure small articles while they undergo filing and other operations. It serves especially to hold the three edged needle or drill, with which it is sometimes necessary to enlarge the orifice of the blowpipe nozzle. See page 117.

Pliers with rough teeth. This instrument serves to hold short

lengths of wire which have to be twisted, or substances which are to be filed, &c.

A Small Anvil, which can be screwed when in use to the edge of a table. This instrument has a square flat top, a flat wedge at one end, and a spike or round conical point at the other end. The wedge has a hole pierced through it. Upon the square part you flatten substances. The hole is used to turn the end of a wire at right angles. The round spike is used to curl wires into rings, to beat plates into cylinders, or to correct any twist in a cylinder. It is therefore useful in putting the brass cork borers into shape, when they happen to get squeezed flat (page 268). The wedge is used in bending wires or plates of metal at various acute or obtuse angles.

The operator will bear in mind, that metals can be bent and hammered into form most readily, when they have been annealed by being heated to redness and allowed to cool slowly.

Files. A flat file, 6 inch, with fine teeth. Another, 9 inch, with coarse teeth. A round rat's tail file, 6 inch: another, 9 inch, the same sort as used for boring corks. A half round file, 6 or 8 inch, the same as used for filing the cork borers (page 267). A triangular file, 3 inch, the same as used for cutting glass tubes (page 248).

A saw with fine teeth, fixed in a bow handle, used for cutting off lengths of wire, pieces of tube, corners of apparatus, &c.

A small quantity of *tinsmith's solder*, and a little powdered rosin, should also be provided, by the help of which and the blowpipe, pieces of tin plate can be readily joined together.

A Drill and Drill Bow. This serves to bore holes in plates of metal, or in the ends or through the sides of metallic wires. It also serves to bore holes in glass, as mentioned at page 250.

A Screw Plate. Adapted to cut projecting screws upon the ends of small wires. It must be accompanied by a set of small steel screws qualified to cut hollow screws to correspond with the projecting screws which are formed by the plate.

It may here be mentioned, that all instruments which are intended to abrade metal, as drills, files, saws, &c., must be moistened with *sweet oil*, while all instruments which are intended to abrade glass, must be moistened with thick *oil of turpentine* having *camphor* dissolved in it.

CEMENTING.—1. When vapours of watery liquors, and such others as are not corrosive, are to be confined, it is sufficient to surround the joining of the receiver to the retort with slips of wet bladder, or of linen, or paper, covered with flour paste, or mucilage of gum-arabic.

2. Soft cement is made of yellow wax melted with half its weight of turpentine and a little Venetian red to give it colour. It can be easily moulded by the fingers, and sticks well to dry substances.

3. For containing the vapours of acid, or highly corrosive

substances, *fat lute* is made use of. This is formed by beating perfectly dry and finely sifted tobacco pipe clay, with painters' drying oil, in a mortar, to such a consistence that it may be moulded by the hand. To use it, it is rolled into cylinders of a convenient size, which are applied, by flattening them, to the joinings of the vessels, which must be quite dry, as the least moisture prevents the lute from adhering. The lute, when applied, is to be covered with slips of linen spread with the lime lute; which slips are to be fastened with pack thread.

4. When penetrating and dissolving vapours are to be confined, the lute to be employed is of quick lime slacked in the air, and beaten into a liquid paste with white of eggs. This must be applied on strips of linen; it is very convenient, as it easily dries, and becomes firm. This lute is very useful for joining broken china ware.

5. For cementing stoneware to metals and wood, litharge and red lead mixed and worked up with spirit of turpentine, makes a good cement. It takes several days to give off the turpentine and become dry and hard.

6. Cement for fastening brass necks upon glass jars, &c.:—4 parts of rosin, 1 of wax, and 1 of finely powdered brick, melted and well mixed together. It is to be put on warm, but care is to be taken not to apply it so hot as to split the glass. It holds very hard.

7. Mix lintseed meal with water, and knead it into a stiff paste. It soon hardens and withstands the fumes of acids and ammonia. It is better if made with lime water, or thin glue. It is charred by a strong heat.

8. Thick gum water, with pipe clay and iron filings. Mix well. It becomes very hard and firm, and is fit to be used where it is required to hold good a considerable time.

9. Plaster of Paris, stirred up with milk, starch water, or thin glue. It hardens immediately, and is very good for securing tubes in flasks, when the corks do not fit well, and gases are to be prepared in them. The cut represents a case where several glass tubes are passed through a perforated stopper of serpentine, (page 272), where a paper jacket is tied round the neck of the flask with string, and the cup so made is filled up with thin plaster of Paris, which applied in this manner, makes a very effective cement.

10. Dissolve melted India rubber in boiling lintseed oil, and afterwards thicken the latter with pipe clay till it forms a stiff mass. The thorough incorporation of the pipe clay demands a great deal of labour. This is a capital cement to be used when acids are to be prepared.

11. *Cement for fastening labels upon bottles.*—Soften and subsequently boil glue in strong vinegar. During the boiling, thicken it with flour. This mixture can be preserved in a soft state without becoming mouldy. It should be put into a glass

bottle, with a wide neck and a ground stopper. When it is to be used, it is taken out of the bottle on the point of a spatula, warmed over the lamp, if too thick for use, and then spread upon the paper. It holds well.—To this method of affixing names to bottles, I may add an account of a *Red Ink for writing upon glass*.—This is made from cinnabar, amber varnish, and oil of turpentine. It readily dries, is not washed off by water, but can be dissolved by spirit. The use of it, is to write upon glass vessels the name of what they contain. Bottles for re-agents, prepared with a white enamel name plate, can be marked with this ink.

12. *Universal Cement.*—Curdle skim milk, press out the whey, break the curd in small pieces, dry it, and grind it in a coffee mill. Take ten ounces of dry curd, one ounce of fresh burnt quicklime, and two scruples of camphor. Mix the whole intimately, and preserve it in small wide mouthed bottles, closely corked. When it is to be used, mix it with a little water, and apply it immediately.

13. *Diamond Cement for Glass or Porcelain.*—Dissolve five or six pieces of gum mastic, as large as peas, in the smallest possible quantity of alcohol. Mix this liquid with two ounces of a strong solution of isinglass, (made by softening and dissolving isinglass in boiling brandy or rum to saturation), having previously incorporated the two ounces of isinglass solution with two or three small pieces of galbanum or gum ammoniac, by trituration. The mixture is to be preserved in a well closed bottle, and is to be gently heated by holding the bottle in hot water at the moment when you are going to use it.

The employment of thoroughly good corks often supersedes the use of cements. It is easier to procure a good cork than to make a bad cork fit air tight by cementing.

Cleansing.—When an experiment is ended, the vessels employed in it should be thoroughly cleansed and put away. Wash your glasses in a tub. If the dirt adheres, soak them well. Do not rub them with sand to get them clean. Use tow and rough ended copper wires to cleanse the inside of glass tubes. Clean very small tubes by means of a slip of whalebone, with a fold of blotting paper about it. A stick and towel can be used in cleansing the inside of large glasses. An old silk handkerchief is very good to clean small glasses with. Oil flasks can be cleaned by a little oil of vitriol. Rosins and turpentine can be cleaned out by alcaline solutions. The insides of glass flasks can frequently be cleaned by shaking pieces of raw potatoe in them with water. Black ashes are of use in other cases, and where mechanical action is indispensable, pyrope or Bohemian garnets, is the best thing to use, being nearly as cheap as leaden shot, and not liable to communicate any impurity. The sooner you cleanse vessels after they are done with, the easier the dirt comes

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off. It is a very troublesome and expensive practice to allow dirty glasses to accumulate.

The young experimenter may excuse a few words respecting the cleansing of his hands from certain symptoms of industry which he may possibly not be desirous of exhibiting before those who have not been initiated into the mysteries of the craft. Colours can often be removed by lemon juice, vinegar, or diluted ammonia. Black stains of charcoal, by rubbing the hands with oil and then washing them with soap and a pretty hard brush. Tar can be removed by oil, and rosin and lack varnish by alcohol. There are a few liquids, to wit, nitric acid, nitrate of silver, chloride of gold, &c., which tinge the skin so strongly that the wearing off of the epidermis is the only means of removal. Such liquids must be handled carefully.

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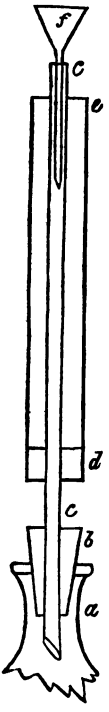
ADDITIONS

TO THE

PRECEDING ARTICLES.

SOLUTION.

MOHR'S CONDENSER.—A case of solution of very frequent occurrence, is that where a solid substance is exposed, for a considerable time, and at a high temperature, to the action of a volatile liquid. This is accompanied by several inconveniences. When, for example, the volatile liquid is valuable, as in the case of ether, sulphuret of carbon, &c., a considerable loss is sustained by the rapid evaporation which takes place. Other liquids, as spirit of wine, undergo continual alteration in their solvent powers, by a partial decomposition. While others, as is the case with the nitric and muriatic acids, disengage vapours that are very offensive to the operator. In experimenting with liquids such as these, it is useful to employ the following condenser, for the contrivance of which we are indebted to Dr F. MOHR of Coblentz.



The mouth of the flask in which the solution is contained, *a*, is closed with a cork, *b*, through which is passed a glass tube, *c*, 12 or 16 inches long, and $\frac{1}{8}$ or $\frac{1}{4}$ inch in diameter. Around the upper part of this tube is fixed another tube, *e*, by means of a cork, *d*. This tube should be nearly one inch wide, but only be two thirds as long as the narrow tube. The space between the two tubes is filled with cold water. When the mixture to be digested is put into the flask *a*, and the cork *b* is adjusted to its mouth, the whole apparatus may be fixed over a lamp, by gripping the wide tube *e* by the clasp of the tube holder, page 41. The volatilised liquid, upon being heated, rises in the tube *c*, but is condensed when it comes to the part surrounded by the cold water, and then flows back into the flask. It is neces-

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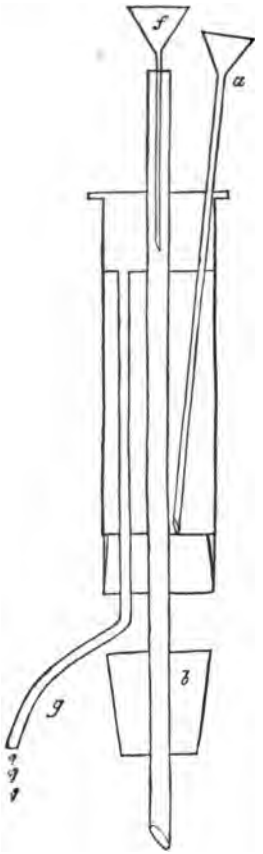
sary to facilitate the dropping down of the condensed liquid from the narrow tube, by grinding the point of the latter *aslant*, as shown in the figure. This prevents the accumulation of liquid in the point of the tube, as happens with narrow tubes that are cut off square. When the water in the tube *e* becomes too hot to condense the rising vapour, it must be poured out and replaced by cold water. Ether can be boiled for a quarter of an hour in an apparatus of this sort without loss.



When pretty large quantities of liquid are operated upon, a larger condenser is necessary, as the water in a small tube becomes too rapidly heated. In this case it answers very well to employ, for the wide tube *e*, a two inch wide cylindrical lamp glass, closing its lower end by a bung. A small addition also is made to the apparatus to facilitate the exchange of cold water for hot, without inverting the flask. The cold water is put in when necessary by a small funnel *a*, with a neck long enough to reach to the bottom of the condenser. The hot water is permitted to escape by a tube *g*, the lower end of which passes through the cork at the bottom of the condenser, and the upper end of which reaches to the surface of the water.

When additional liquid requires to be put into the flasks, the small funnels *f f* are employed.

The central tubes, *c*, should be provided with corks, *b*, of various sizes, to suit flasks with wide or narrow mouths.

In such operations as the solution of platinum in aqua regia, which takes place very slowly, and requires a frequent renewal of the acid, a condenser of this kind is equally economical and convenient, producing both a saving of acid and preventing the otherwise abundant diffusion of acid vapours in the operator's apartment.

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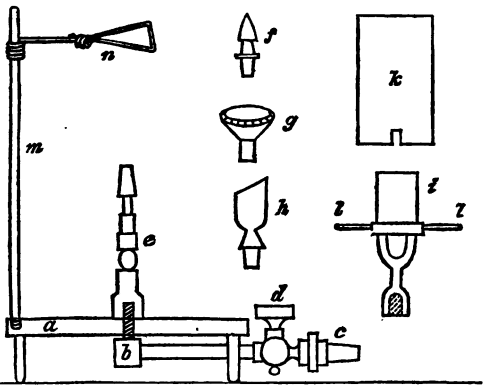
APPLICATION OF HEAT.

Gas Light Apparatus.

The following figures exhibit a set of apparatus for forming a portable gas light, adapted equally to the work table and the lecture room. *a*, is a circular cast iron table, five inches in diameter, and supported on three feet, each an inch in length. This table is adapted to hold the cylinder of the lamp furnace, page 24, and therefore to supply heat in any of the operations



for which the lamp furnace is recommended; and, in order to render gas available at various heights above the work table, this iron gas table can be raised to any requisite altitude by means of the table shaped branch of the universal support, a figure of which will be given under the head of "Supports for Apparatus," in the next section. See page 283.

The gas is brought to this moveable iron table from the nearest fixed gas pipe, on the ceiling, the wall, or below the floor, as the locality may render most convenient, by means either of flexible spring pipe, or of soft metallic pipe; the latter being generally preferable on account of it costing only the twelfth part of the price of the former. You take therefore a leaden pipe of the requisite length. You unscrew the nozzle of the nearest gas light, and fasten your leaden pipe to the end of the gas pipe by a tubular connector of Indian rubber, as described at page 225. You then connect the other end of the leaden pipe, by another tube of Indian rubber, with the coupling screw of your portable gas light, which I have marked *c*, in the above figure. In some cases it is, however, better to have a foot or two of flexible spring tube cemented to this coupling screw, and to provide a second coupling screw to connect the flexible tube with the leaden tube, fixed, to be out of the way of mischief, under some part of the work table. By means, then, of a flexible

metallic pipe with one or two caoutchouc connectors, gas can be readily brought to the coupling screw *c*. To this screw is cemented the stop cock *d b*, which bends at a right angle at *b*, and terminates in a small screw which passes through a hole bored in the middle of the iron table *a*. Hence the gas can be permitted to escape from the end *b*, or be shut off at pleasure by means of the stop cock *d*. I have consequently now only to describe the burners, or jets, which are employed to produce gas flames of various sizes and forms, for different experiments. These burners are represented by *f g h i*.

f is the common single jet burner, the flame of which serves the same purposes as the flame of the small spirit and oil lamps.

g is a thistle burner, with ten holes disposed in a ring. It gives a large circular flame, adapted for heating evaporating basins, large flasks, and other objects of considerable bulk.

h is the blowpipe burner, which I have described at page 114. The whole of these jets are made to fit the upper orifice of the socket *e*, which can be screwed upon, or unscrewed from, the stop cock *b*, at pleasure.

i is an ordinary argand burner which gives a much more intense heat than any of the foregoing jets. It is provided with a separate socket and screw, adapted to the point *b*, so that when this burner is used, the socket *e* is displaced. *k* is an iron chimney for the argand burner, which is supported when in use, by three thin brass wires, screwed at equidistant points into the burner *i*, as is represented at *l l*. Three small equidistant notches are cut in the lower margin of the cylinder *k*, to adapt it to these three projecting wires. The chimney is three inches long, and two inches broad, or it is two inches each way above the level of the burner. The brass rod *m*, screws into the iron table *a*, but is removeable at pleasure. The use of it is by means of the sliding triangle *n*, to hold crucibles and other small vessels over the flame of one or other of the jets.

When a long narrow tin cylinder, having a row of holes round the bottom edge, and a flat sieve of wire gauze fixed upon the upper end, is put over the open mouth of the stop cock *b*, and gas is allowed to mix within the cylinder with atmospheric air, and is inflamed at the upper side of the wire gauze, a large, flat, blue, unsmoking flame is produced, which can be usefully applied in a great number of operations.

LAMP FURNACE.—Since the article at page 24—28 was printed, several useful additions have been made to the little lamp furnace, namely:—

Sand Baths.—Hemispherical capsules of very thin stoneware, strengthened by a ring of stoneware round the edge, as represented in the marginal figure, answer very well for holding hot sand so as to constitute sand baths for the lamp furnace. Two sizes are now made for this purpose; the smallest 3½ inches, the largest 4½ inches in dia-

meter. They serve to regulate the application of heat to flasks and retorts, and frequently prevent the fracture of glass vessels. They are therefore of equal use in solution and in distillation. See page 196.

Copper basins of the same shape are no doubt preferable for this purpose, but they are five times more expensive.

Dome for covering Retorts in Distillation.—See page 196, and the additional article on "Distillation." The price of this dome is 4d.

Stone Oil Lamp.—This is intended to afford a cheap and gentle heat for slow evaporations and continued digestions over the sand bath. It consists of a bottle similar to the lamp *a*, page 24, but it has a neck similar to that of the stone still described in a subsequent article, the object of the alteration being to let the wick holder sit *within* the neck of the lamp, in order to prevent the overflowing of the oil. The price of this lamp is 8d.

Small Perforated Ring.—An extra perforated ring is now made for the lamp furnace, in addition to the one marked *c*, at page 24. It is small enough to fit into the large ring, and is intended to support flasks and retorts of the capacity of 2 or 3 ounces, which are too narrow to be held by the large ring. The price of this ring is 2d.

Stone Still for Preparing Pure Water, &c.—I shall describe this under the head of "Distillation," page 289.

Stone Water Bath.—See the additional article on "Evaporation," page 285.

Large Spirit Lamp.—The importance of the large spirit lamp to the analytical chemist, has been already described in the article at page 19. I have only to add, in this place, an account of a *considerable reduction in the price of this useful apparatus*, which will take place in consequence of my having manufactured a large quantity of them. The new lamp is made from a pattern kindly furnished me by Professor Liebig of Giessen. It has the form and dimensions which have been found to afford the greatest fusing power, and it is provided with the cover and chimney contrived by Professor Liebig, and alluded to at page 20 of this work. The material of which the lamp is made is tin plate, japanned brown; this metal having been found, by recent trials, to make a better working lamp than brass. The chimney is of black iron. The price of this lamp, without a stand, is 12s. It can be fitted up on a rod adapted to support crucibles, basins, and flasks, at from 4s to 6s additional, according to the quantity of extra apparatus, and the elegance of the style of fitting. See "Supports," in the Appendix.

So powerful is the heat afforded by this lamp, and yet so much under control, that the operator has it in his power to use with effect, or to economise, at will, all the heat which it affords. I can safely say, that in consequence of this quality, it is possible during a very short course of experiments, to save the cost of

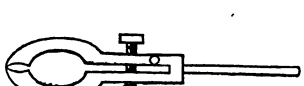
the lamp out of the price of the fuel which would be burned to waste in lamps of inferior quality. I believe, indeed, that the use of this lamp is in many operations attended with more economy than the use of the small spirit lamp, so great is the advantage which attends the power of raising or depressing the wick according to the progress of the operation, an advantage which is lost in the small lamps, where there is no means of regulating the height of the wick. Hence there is often a considerable and unavoidable waste of spirit when the small lamp is used. To illustrate this point, let us suppose that it is necessary to apply a variable heat to an object. If you use the large lamp, you give a strong or a feeble heat by simply raising or depressing the wick; and in the latter case, no more spirit is burnt than the occasion requires, and both object and lamp remain stationary. When you use the small lamp for this purpose, you can only give a strong heat by pulling up the wick pretty high, and when you want to give a feeble heat, almost the only plan is to increase the distance between the lamp and the object. The spirit then burns to waste. If to prevent this, you endeavour to push in the wick while the operation is going on, you are in danger of putting out the light, and possibly of spoiling your operation.

SUPPORTS FOR APPARATUS.

Universal Support.—I have described at page 39, a powerful wooden support devised by Sefstroem, and adapted to hold at variable heights, not exceeding 18 inches from the table, such vessels as large tubes, condensers, and retorts. And at page 202, I have depicted a modification of this apparatus, as it is now made for sale in Glasgow; what I have to add in this place, is a description of three additional branch holders, contrived to render this apparatus of more universal application.

It is necessary to premise that the apparatus which is figured at page 202, is sold in two parts. The first comprises what may be called the essential part of Sefstroem's holder. It is the sort of *Press* which is represented apart from the rod at page 39. The other portion of the apparatus, consists of the upright rod, the foot, and the square block or parallelopepidon of wood, by which the Press is connected to the rod when required for service.

The same rod, foot and block, which serve to hold Sefstroem's Press, serve also to hold the three branches now to be described, each of which is furnished with a round rod adapted to the socket that is bored in the block.



The Vice.—This is a modification of an instrument recommended by Berzelius, and described at page 40. It is so contrived as to be able to bite both large and small tubes.

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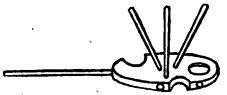
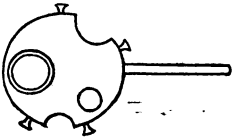
THE TABLE.—This branch is rather of complex structure. It is a combination of the set of Berzelius's supports, described at page 44. The flat part is the table marked A, in the cut referred to. This table is five inches in diameter, and serves to support the lamp furnace, page 24, and the gas light table, page 279. The crook B, page 44, is supplied by two notches in the sides of the table, one adapted for tubes of an inch in diameter, the other for tubes of two inches in diameter, such as the condenser, page 201. Brass headed nails are inserted on each side of these notches, to afford the means of fastening the tubes to the table by means of string or thin metallic wire, slips of Indian rubber being put between the table and the tube to facilitate their adhesion. The pegs on the reverse of the table are intended to supply the place of the pegs depicted at c, page 44. They serve to hold round bottomed vessels—basins or flasks.



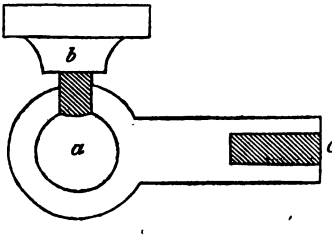


The table is pierced with two holes. One of these is cylindrical, and intended for the support of tubes placed horizontally when the table is fixed vertically, as shown in the under figure. The other perforation is conical, and is intended to support large funnels employed in the filtration of heavy masses of liquid.

THE CYLINDER HOLDER.—This is nearly a counterpart of Gahn's holder, described at page 222, fig. B. But differs from it in being without the cavity and screw F N, and consequently without the supporting rods D I, in the place of which a long peg is fastened upon the instrument at the end *a b*, by which it can be fixed to the block of the upright rod described above.

Any other variety of branch can be adjusted to the universal support in the same manner, according to the particular object in view.

LAMP ROD AND HOLDER FOR EVAPORATING BASINS.—At page 37, I recommended the practice of securing triangles intended for the support of large evaporating basins, by fixing them to upright rods by means of screw nuts; but I committed the oversight of not describing the screw nut, which is best adapted to that purpose, which omission I now supply. *a* is a brass sphere $\frac{5}{8}$ inch in diameter, bored with a hole, for the reception of a brass rod of $\frac{1}{4}$ inch in diameter, to which rod it can be affixed by means of the flat headed screw *b*. A brass



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rod $\frac{5}{8}$ inch wide, and 1 inch long, is fixed to the sphere at a right angle to the bore *a*, and a female screw *c* is sunk in the end of this rod for the reception of screws cut upon the ends of wire triangles, lamp rods, and other instruments which require to be supported horizontally.

The following articles are requisite to complete this apparatus:

1. A brass rod, 18 inches long, and about $\frac{1}{4}$ inch diameter.
2. A foot, consisting of an oblong board, as represented at page 19, or a cast iron triangular trivet with three feet, which I have now in course of manufacture for this purpose.
3. A glazed earthenware pan, of 8 or 12 inches diameter, and $1\frac{1}{4}$ inch high, fixable to the foot, and intended to catch any liquor which may be spilt over, and so prevent the loss of the liquor and the soiling of the table.
4. Branches to screw into the socket to support various objects; as a square iron rod to support the large spirit lamp; a ring to support a sand bath; a triangle to support a basin, &c.

TESTING.

Dropping Tubes.—Refer to the figures on page 58. In cases where tests or other liquids are to be applied in single drops, the tubes by which they are transvased should be wide at one end and nearly closed at the other, the orifice left open not being above $\frac{1}{20}$ inch in diameter. This has been already explained; but I have omitted to state that it is the *wide end* of the tube which should be *dipped into the liquid*, so that the test bottle, figured on page 58, is misdrawn. The tube should be inverted, and the contracted end project above the cork. The application of liquids in drops by this method, will be found very easy to manage.

It should have been mentioned at page 58, that the dropping tube with a bulb is useful, when you have to remove liquors by suction from above powders without disturbing the latter, and also when liquids have to be removed from a flat surface, an example of which is given at page 242.

Improved Tube Frame.—The tube frame depicted on pages 51, 52, has been farther improved by making the pegs of yellow glazed earthenware, and the rest of the apparatus of polished black wood. Thus constructed, it is much easier to keep clean than when made throughout of white wood. The price of it thus improved, namely, of the large size, with 8 pegs for 6-inch tubes, is 2s.

Stock Tube Rack.—I have constructed a tube rack for holding three dozen of tube vessels for use in a Laboratory where such vessels may be often in request. It consists of a black

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wooden foot, with four rows of glazed yellow earthenware pegs, each row containing nine pegs of the following size:—

1st row, 1½ inch, ¼ inch thick.
2nd row, 2¼ inch, ¼ inch thick.
3rd row, 3 inch, ¼ inch thick.
4th row, 3½ inch, ¼ inch thick.

This rack will contain tube vessels of all the sizes which are commonly used to hold liquids. It should be considered a fixture in the Laboratory, and when the tubes are required for use, they should be transferred to a tube frame with holes. Smaller sizes of tube vessels than those adapted for the above rack, are generally used for dry operations, sublimations, &c., and should be kept along with the blowpipe apparatus.

FILTRATION.

Berlin Porcelain Funnel Holder.—This instrument is of the shape and size of the earthenware funnel holder described at page 67. It is of white porcelain and glazed on the upper surface and in the ring F, but not in the hole *r w*. It is fitted up in the style shown at page 66 (the lower figure). The rod and foot are of polished black wood. The rod is nine inches high. The price of the apparatus, complete, is 1s. 6d.

In the figure referred to at page 66, the upper end of the rod *c* is represented as *pointed*. It ought to be *flat*, because it is often necessary to alter the position of the part *b* and *d* with the fingers of the right hand, and it is then necessary to steady the rod *c* by pressing the thumb upon its top. This is a small matter to refer to, but good manipulation consists in attention to small matters.

EVAPORATION.

Stoneware Water Bath.—The water bath described at page 89, I have now imitated in stoneware. The size of it is 4½ inches diameter. It can be used very conveniently with the lamp furnace. The price of it (two pieces) is 9d.

Stoneware Evaporating Basins.—I have succeeded in procuring a supply of evaporating basins of salt glazed stoneware. They are mostly shaped like the third variety of the Berlin porcelain basins enumerated at page 85, being one third as deep as they are broad, and having an overhanging rim; and only a few of them have spouts. They are very thin and uniform in substance, and well glazed. They can be heated over sand, or even over the flame of the lamp if applied cautiously. For

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slow evaporation and for crystallisation they answer extremely well, especially for the latter, as the slight roughnesses on the surface facilitate the deposition of crystals. They can also be used in evaporating to dryness, provided the heat be moderated towards the end of the process. But they cannot be heated to dryness in contact with the point of a strong and steady spirit flame, without a chance of splitting. This chance is greatly diminished by placing the evaporating basin over hot sand, contained in a stoneware sand bath, or by fixing the evaporating basin at some height above the flame when the solution is concentrated, so as to cause the substance to dry gradually. I employ short cylinders of stoneware, to lengthen the lamp furnace for this purpose.

These basins are not adapted for use in accurate experiments with weighed quantities; but they will probably prove useful in the *preparation* of many chemical substances; as, for example, in the pharmaceutical processes which occupy the attention of practical students of medical chemistry; in the evaporations which so frequently occur in the laboratories of manufacturing chemists; in the preparation and examination of dyestuffs and drugs in the colour shops of calico printers; and in many other cases of equal importance.

The sizes and prices of these stoneware basins are mentioned in the Appendix.

Handle for Basins.—It is sometimes necessary to lift hot basins, for which purpose the tin holder, figured on page 41, is a useful instrument. You hold the end *a* in your right hand; grip the edge of the basin between the bent ends *b*, and secure it there by pushing down the coil *c* by means of the thumb and forefinger of the right hand. However, this method of lifting a basin can only be used when the basin is small, and not very full of liquid.

IGNITION.

New Berlin Porcelain Crucibles.—Since the description of Berlin glazed crucibles at page 98 was printed, I have received two new sorts. The form of these is cylindrical, like the figure of the little crucible in the jacket on page 97. The cover is different from the cover depicted on page 98, inasmuch as the perpendicular rim which holds it on the crucible dips inside the crucible instead of covering the outer edge. There are two sizes of this new crucible:—

No. 1.—1¼ inch by 1 inch, price 8d.
2.—1¾ inch by 1½ inch, price 9d.

These are the prices in Glasgow.

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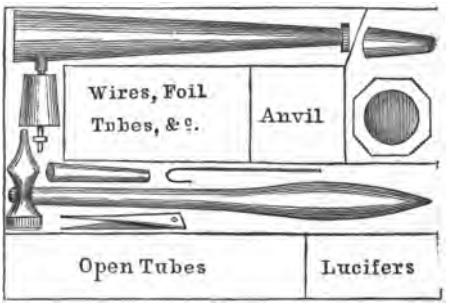
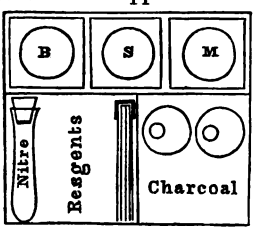
BLOWPIPE APPARATUS.

Boxes for Fluxes and Apparatus.—At pages 127, 128, and 130, I have described several methods of packing and arranging the articles required for use in analysis by the blowpipe. To the accounts there given, I now add another, relative to a pair of boxes which I have recently contrived, and find to be convenient.



The figure represents a box 9 inches long, 6 inches broad, and 1 inch deep, divided by fixed partitions into six divisions. It has a cover which lifts off, and forms a tray to hold the lamp when in use. The box and cover are made of tinplate, japanned both within and without.

The largest division contains the blowpipe fitted ready for use, the platinum tongs, the hammer, the charcoal borer, the charcoal holder, the tongs for trimming the lamp, the rod for supporting the lamp when the latter is dismounted, the file, and other small tools, all disposed, as shown by the figure, better than I can tell in words. Another space contains about two dozen of 6 inch hard open tubes for sublimation; another, lucifer matches, or, in their place, substances for analysis; another, the agate mortar; another, the anvil; and the last space contains the platinum wires and foils, the brass wire, the closed tubes, and other small supports.



This cut represents a box with divisions for fluxes, and prepared plates of charcoal. It is made of japanned tin plate like the foregoing, and provided with a cover. It is $5\frac{1}{2}$ inches long, $4\frac{1}{2}$ inches wide, and nearly 2 inches deep. B S M, represent a space for three square glass bottles to contain borax, soda, and microcosmic salt. The bottles

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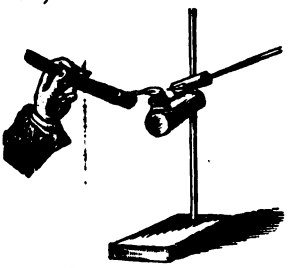
which I use for this purpose are the square ink bottles, commonly used for portable writing desks. They are closed by corks with plated tops. Below this space is another which holds about two dozen of prepared plates of charcoal, and a third space which contains about a dozen of 2½ inch glass tubes, closed by corks, for storing the remainder of the re-agents, viz., test paper, nitre, and the other substances particularised at page 127.

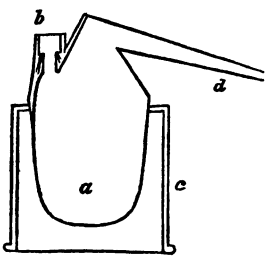


When at home, you always keep your lamp mounted ready for use on such a stand as is represented in the annexed figure, which stand is simply a wooden rod fixed into a parallelogram of wood. There is therefore no occasion to provide any place for the lamp in either of these boxes. In travelling, you have to take another sort of lamp, provided with a screw cap to cover the wick holder, and prevent the escape of oil. This lamp you make into a separate package. A wooden rod for supporting it can be carried in the large box alongside the hammer; and to provide the means of fixing the rod, a small tin cylinder is soldered upon the inner side of the cover of the large box, by means of which, and an intermediate cork, the rod and lamp can be fixed upon the cover, as upon a foot. Hence it is unnecessary to carry about any separate basis for the lamp rod.

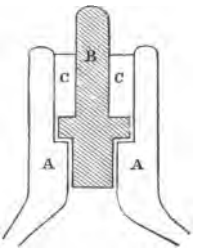
The price of this pair of japanned boxes is 7s., or with a complete set of apparatus, 42s.

DISTILLATION.

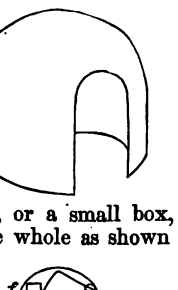
Stoneware Still.—The annexed figure represents a stone ware still, or a vessel betwixt a retort and a still, which will be found useful in many common cases of distillation, such as the preparation of distilled water, the purification of muriatic acid, and a great number of other processes which I shall have abundant opportunities of showing hereafter, —*a* is the still, *b* the tubulure, *d* the neck; all in one piece. The height of the vessel is 6 inches, the breadth, at the widest part, 3½ inches, the capacity 16 fluid ounces. *c* is a cylinder of the same material as the still, 4 inches high, 4 inches wide, open at both

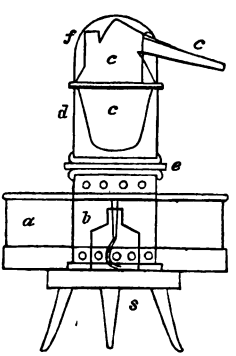


ends, and with a fixed rim at the top, adapted to support the still in the manner shown by the figure. The stopper for the tubulure *b* is peculiar, and is for the sake of perspicuity represented in the margin in its full size. A A indicate a section of the tubulure *b*, and show the substance and proportions of the neck.—The shaded mass B, is a section of the stopper, and the spaces c c, represent a mass of plaster of Paris, which is poured in above the stopper to make an air tight juncture.



Instructions for Distilling Water by means of this Stone Still. Pour into the still eight or ten ounces of water. Close the tubulure *b* with a cork. Then take the lamp *a*, the cylinder *b*, and the ring top *c*, of the lamp furnace, described at page 24; the stone dome for distillation, described at page 196, and of which a figure is given in the margin; the pneumatic trough described at page 214; and a small wooden stool with three legs, or a small box, 8 or 10 inches in height; and arrange the whole as shown by the figure in the margin. *s* is the stool, *a* is the pneumatic trough, *b* is the lamp furnace, *e* is the ring top of the furnace, *d* is the cylinder which serves to support the still, and which differs from the cylinder of the furnace, in being shorter and without air holes. *c c c*, is the still in one piece, *f* is the dome.





All being thus arranged, lift up the cylinder *d*, light the lamp *b*, replace the still upon *e*, and let the apparatus rest till the water begins to boil, which will be in a few minutes.

The *use* of the tool *s*, is to elevate the whole apparatus to a sufficient height above the table to permit the still to be conveniently connected with a condensing apparatus, of which I shall speak presently. The use of the trough *a*, is to receive the con-

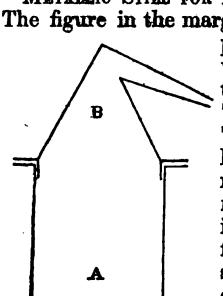
tents of the still if it should break. The use of the lamp cylinder and ring *b* and *e*, I have already sufficiently illustrated. The use of the cylinder *d*, and the dome *f*, is to retain a mass of hot air round the entire surface of the retort, and so to promote a rapid evaporating within it, which purpose this arrangement accomplishes. In a short time a strong current of steam issues from the neck of the still. The condenser described at page 201, previously filled with water, and properly supported by the holder described at page 202, is then adjusted to the neck of the still, and a flask is placed over the lower end of the glass condensing tube, for the purpose of receiving the distilled water. No other care is then required than that of keeping the condenser duly supplied with cold water. By means of this apparatus, and the small stone spirit lamp, or a single jet gas flame, pure water can be prepared with great facility.

To purify Muriatic Acid by means of this Still.—According to Professor CLARK, the best method of purifying muriatic acid is to dilute it to the specific gravity of 1·111; to add a little protochloride of tin, or a little metallic tin, and then to distil. Acid of this specific gravity vaporises without either gaining or losing strength.

The diluted acid is to be put into the stone still, the tubulure is to be closed with its stone stopper, and cemented air tight with plaster of Paris, which is to be poured in a liquid state into the cavity c c, over the stopper in the tubulure of the still, as I have mentioned and figured at page 289.

The distillation of the acid is then effected in the same manner as the distillation of water.

METALLIC STILL FOR DISTILLING WATER AND VOLATILE OILS.—The figure in the margin represents a small still formed of tin plate, which can be employed to distil water, alcohol, and odoriferous oils, in the manner described at pages 187-191. This still consists of two parts, A and B. The former is a cylindrical pan, 3 inches high, and 3 inches in diameter, with a flat rim bent outwards, as shown in the figure. B is a conical head, 3 inches high, and 3 inches wide at the base, with a horizontal flat rim and a vertical rim, both represented in the section, and adapted to fit closely to the sides and the flat rim of the pan A, so as to prevent the egress of steam at the juncture. The head is provided with a neck to convey steam into a cooling apparatus.



When employed to distil water or alcohol, this still is mounted in the same manner as the stone still which I have just described, and as figured on page 289.

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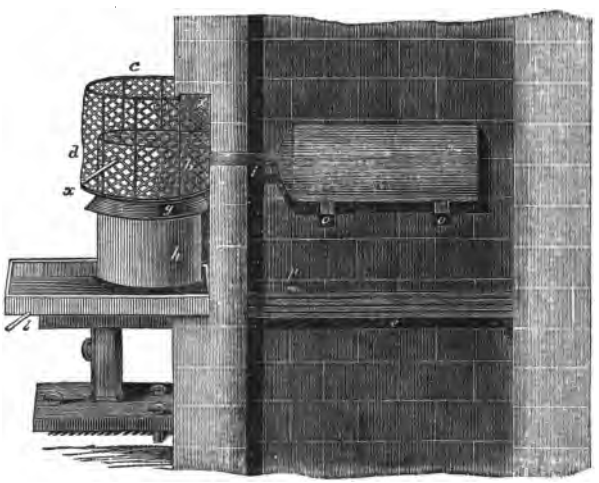
When employed to distil volatile oils, the brass or tin plate disc represented at page 189 is employed, for the purpose described at the place referred to. The distillation is commenced in this case with about an inch depth of water in the pan A, below the perforated disc. The cylinder *d*, and the dome *f*, are of precisely the same service when used with a tin as with a stone still. The flat rim round the upper edge of the tin still should sit so closely upon the upper edge of the cylinder *d*, as to prevent the passage of hot air betwixt them. It should also be of such a size as to afford a resting place for the dome *f*, page 289.



DISTILLATION OF POTASSIUM.

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APPENDIX.

PRICES OF CHEMICAL APPARATUS

AND OF

CABINETS OF ROCKS AND MINERALS,

ON SALE BY

RICHARD GRIFFIN & CO.,

BOOKSELLERS AND STATIONERS, GLASGOW.

COUNTRY orders, accompanied by a remittance, will be promptly executed. The expense of packing cases is chargeable in addition to the price of the articles, at the rate of about 1s. for 20s. worth of goods; but when the order contains many very bulky or very fragile articles, the expense of packing is somewhat higher. The greatest care will be taken to pack the goods securely; but R. G. & Co. do not hold themselves responsible for the breakage which may be produced by the carelessness of carriers. Goods can be forwarded to England by steam to Liverpool, and thence by railway or canal; or by canal to Leith, and thence by steam or smack to Newcastle, Hull, or London. No charge is made for shipping the goods in Glasgow.

Dealers in Philosophical apparatus will be supplied at a very liberal rate of discount for prompt payment.

Gentlemen who may be inclined to purchase this apparatus of dealers resident in towns at a distance from Glasgow, are reminded that the prices of the articles must necessarily be higher there than they are quoted in this catalogue; because the dealer in every case requires to be compensated for his charges of packing, carriage, and accidental breakage. The prices here given are the prices *in Glasgow*. The charges of transporting the apparatus to a distance falls unavoidably upon the consumer.

When the prices given in the APPENDIX differ from those given in the body of the work, those in the Appendix are to be considered correct.

The pages referred to in "CHEMICAL RECREATIONS," present figures or descriptions of the apparatus.

When no price is affixed, the article is in course of manufacture, and the price not ascertained. Such omissions will be supplied by the publication of a Supplementary Catalogue in the next part of CHEMICAL RECREATIONS. Many of these articles will, however, be ready for sale in a few weeks or days.

Written orders for apparatus from this Catalogue should contain the *letters and figures* prefixed to the desired articles, to prevent misapprehension.

Glasgow, Nov. 30th, 1837.

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A.—APPARATUS FOR PULVERISATION.

		s.	d.
A 1	Anvil for Blowpipe Experiments, square block of hardened steel, page 4,	3	
A 2	Steel Hammer for ditto, pages 4, 128,	2	
A 3	Agate Mortar and Pestle, page 3, 1½ inch diameter,	7	
A 4	Ditto, ditto, 2 ditto,		
A 5	— — 2½ —		
A 6	— — 3 —		
A 7	Small Berlin Porcelain Pestle and Mortar, 1½ inch diameter, and shallow, glazed within, for blowpipe experiments, in lieu of Agate Mortar,	1	
	Berlin Porcelain Mortars with Pestles, glazed without, biscuit within, the pestles in one piece, page 3:—		
A 8	No. 0.—2 inches diameter,	1	
A 9	Ditto, 1.—3½ ditto,	2	6
A 10	— 2.—4½ —	4	
A 11	— 3.—5½ —	5	
	Berlin Porcelain Apothecaries' Mortars, for grinding and mixing powders, broad and shallow, without spout, with a rim to prevent the matter being thrown out, the pestles with broad ends, and in one piece, page 3:—		
A 12	No. 1.—5½ inches diameter,	4	6
A 13	Ditto, 2.—7½ ditto,	7	
A 14	" 3.—9 —	9	
	Serpentine Mortar and Pestle, very finely polished:—		
A 15	2 inches diameter,	1	
A 16	Ditto, 3 ditto,	1	6
A 17	— 4 —	2	
A 18	— 5 —	2	6

B.—APPARATUS FOR SOLUTION.

	Flint Glass Flasks with thin bottoms, for boiling solutions, the lips not turned:—		
B 1	With flat bottom, 2 ounce,		7
B 2	Ditto, 4 —		8
B 3	— 6 —		8
B 4	— 8 —		10
B 5	With round bottom, 2 — fig. A, page 12,		5
B 6	Ditto, 3 — pear shaped, with long neck, fig. *e*, page 24,		6
B 7	— 8 — with long neck, ditto,		8
	Hard German Glass Flasks, with thin bottoms and bordered mouths, for the reception of corks, and therefore equally adapted for gas bottles:—		
B 8	2 ounce capacity,		
B 9	Ditto, 3 ditto,		
B 10	— 4 —		
B 11	— 6 —		
B 12	— 10 —		
B 13	— ½ — very light, for analytical experiments,		6

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		s.	d.
B 14	Boiling Tube, six inches by one inch, hard German glass, sealed and bordered, intended for the solution of metals, &c., on the small scale, fig. *c*, page 8, . See "Test Tubes," for other sizes of tube vessels.		4
B 15	Ditto, with round bulb, page 8, hard glass, . .	1	
B 16	" with pear shaped bulb, page 8, hard glass, .	1	
B 17	Oval Flask, with turned lip for the reception of a cork, 6 oz. flint glass, page 209, upper figure, . .	1	4
	Berlin Porcelain Digester, or Flask, egg-shaped, with wide mouth, glazed within and without, useful in dissolved metals in acids, also as crucibles, page 13:—		
B 18	Small size, $2\frac{1}{2}$ by $1\frac{3}{4}$ inch, . . .	1	
B 19	Ditto, Large size, $2\frac{3}{4}$ by $2\frac{1}{4}$ inch, . . .	1	

C.—APPLICATION OF HEAT.

LAMP FURNACE, pages 24, 280.

C 1	Stoneware Spirit Lamp, with cover and tin wick holder, page 24, *a*, ...		6
C 2	Cylinder for ditto, serving as a chimney to steady the flame, and as a support for vessels over it, page 24, *b*,		8
C 3	Five inch Ring Top for ditto, page 24, *c*, page 25, III. serves to support 4 oz. to 8 oz. flasks, . .		2
C 4	Three inch Ring Top, to contract the orifice of the former ring, and support 2 oz. and 3 oz. flasks, page 281, .		2
C 5	Dome to cover Flasks when boiling, and prevent the radiation of heat, page 24, *d*, ...		3
C 6	Sand Bath, $3\frac{1}{2}$ inch, for small flasks and retorts, adapted to the large ring top, page 280, . . .		4
C 7	Sand Bath, $4\frac{1}{2}$ inches, adapted to the top of cylinder C 2,		4
C 8	Dome to cover 2 oz. to 6 oz. retorts in distillation, when placed on the ring top or sand baths, and prevent condensation in the upper part of the retort, pages 281, 289, ...		4
C 9	Water Bath, $4\frac{1}{2}$ inch, for drying powders at a steam heat, adapted to cylinder C 2, in two pieces—boiler and capsule, page 285, ...		9
C 10	Oil Lamp for this Furnace, to be used in slow evaporations and digestions, with wick holder and cover, page 281, ...		8
C 11	Set of three Plain Cylinders of different sizes, to lengthen the cylinder C 2, and adjust vessels at proper heights from the lamp, and thus modify the intensity of the heat applied, ... *the set*	1	
C 12	Still or Stoppered Retort, adapted for the distillation of water or of acids, 16 oz. capacity, page 288, .	1	
C 13	Flask with round thin bottom and wide mouth, for preparing such gases as require heat, 6 oz. to 10 oz.,		4
C 14	Another Flask, with thin round bottom, adapted for the preparation of acids, with a neck such as is described at page 289, 12 oz., ...		8
C 15	Another Flask, with thin round bottom, 12 oz., with a neck 2 inches broad, on the same plan as the last, and with a cover, ...		9
	All the above 15 articles are made of salt glazed stoneware.		

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		s.	d.
C 16	Iron Trellis for supporting capsules and flat bottomed vessels on cylinder C 2, over the flame, page 26,		4
C 17	Square Tin Plate for the same purpose, 5 inch,		2
C 18	Ditto, 3½ inch, which closes the large ring top C 3,		1
C 19	The total cost of this LAMP FURNACE, comprising 18 articles, is	8	6
C 20	The cost of the lamp furnace, omitting the articles marked C 9, 12 to 15,	5	
C 21	The cost of such parts of the Lamp Furnace as are necessary for small solutions, evaporations, and ignitions, viz., C 1 to 7, and 16 to 18,	3	
C 22	LARGE SPIRIT LAMP, WITH CIRCULAR WICK, with the improvements of Berzelius, Mitscherlich, and Liebig, japanned tin plate, with iron chimney, pages 19, 281,	12	
C 23	Cotton Wicks for this lamp, *per dozen*,		
C 24	Crucible Jacket to increase the igniting power of the lamp for crucible operations,		
	GAS-LIGHT FITTINGS, page 279.		
C 25	Stop Cock and Coupling Screw,	2	
C 26	Iron Table, with Brass Rod and Triangle,	1	6
C 27	Socket and Single Jet,	1	
C 28	Thistle Burner, 10 holes,	1	6
C 29	Argand Burner and Iron Chimney,	4	6
C 30	Blowpipe Burner, page 114,	1	6
C 31	Flexible Pipe, seven feet long,	1	6
C 32	Cost of the whole gas fittings, C 25 to 31,	13	6
C 33	Glass Spirit Lamp, with cap and brass wick holder, page 17, 2 ounce,	2	6
C 34	Ditto, 4 ounce,	3	
C 35	— 7 —	3	6
C 36	— with a silver wick holder, after Berzelius, 4 oz.,	8	
C 37	Japanned Tin Spirit Lamp, with cover, page 18,	1	
C 38	Japanned Tin Oil Lamp, with cover, page 18,	1	
C 39	Stoneware Furnace for Evaporation, to be used with charcoal,		
C 40	Stoneware Furnace for Distillation and Crucible Operations, to be used with charcoal,		
C 41	Luhme's Universal Portable Furnace, sheet iron, lined with fire clay, page 29,	40	

D.—SUPPORTS FOR APPARATUS.

D 1	Triangle Support for Retorts, Crucibles, &c., page 36, 9 inch brass rod and triangle, with wooden foot	1	
D 2	Tube Holder for supporting small glass vessels above a lamp, page 43, japanned iron, with wooden rod and foot,	1	
D 3	Tube Holder without the rod and foot,		8
D 4	China Funnel Holder, adapted for any size of funnel, with wooden rod and foot, page 66, 67,	1	
D 5	Ditto, entirely made of wood,		8
D 6	— the branch of Berlin porcelain and the rod and foot of polished black wood,	1	6
D 7	Set of Six Blocks of Wood, for adjusting apparatus, 4 inches square, and respectively 4, 2, 1, ½, ¼, ⅛ inches thick, page 36, *the set*	1	6

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		s.	d.
D 8	Support for Blowpipe Lamp, wooden rod and foot, black,		6
	Universal Support, comprising a wooden foot and 18 inch rod with nut and screw, and four branches to support apparatus of various forms, page 282, made of hard wood stained black:—		
D 9	The Rod, Foot, and Nutt alone, . . .	3	
D 10	The Table Shaped Branch, ...	3	
D 11	The Vice Shaped Branch, ...	2	6
D 12	The Press Shaped Branch, ...	3	6
D 13	The Cylinder Holder	2	
D 14	The Set of Supports, D 9 to 13, complete for . .	14	
	The same, varnished with copal 1s 6d additional.		
	The rod D 9, and any branch supplied separately.		
	SUPPORTS FOR LARGE SPIRIT LAMP, BASINS, &c.		
D 15	Cast Iron Triangular Foot for retort stands, measuring 5 inches each side, with three feet an inch high .		
D 16	Ditto, measuring 8 inches each side . . .		
D 17	Brass Rod 18 inch, for the large foot, with screws to fix it,		
D 18	Brass Rod 12 inch, for the small foot, with screws to fix it,		
D 19	Glazed Earthenware Pan, to place upon these feet below lamps, basins, &c., 5 inches diameter, ¾ inch deep,		8
D 20	Ditto, 8 inches diameter, 1 inch deep, . . .	1	
D 21	— 12 inches diameter, 1¼ inch deep, . .	1	6
D 22	Socket and Screw to hold rings and triangles to the large rod, page 283, ...		
D 23	Set of three Rings and triangles for ditto . .		
D 24	Square Iron Rod to fix the large circular wick spirit lamp to the upright rod, D 17, ...		
D 25	Triangle and Screw Socket for the small rod D 18, .		
D 26	*The Set of Lamp Supports*, comprising D 16, 17, 21, three of 22, 23, 24, ...		
D 27	Set adapted merely to hold the lamp, D 16, 17, 22, 24, .		
D 28	Square Iron Bar, with wooden rod adapted to D 9, to support the Large Lamp, C 22, . . .		

E.—TESTING.

Test Tubes, hard German glass, straight, sealed at one end, bordered at the mouth, page 8, *c.*:—

E 1	1¼	inch long by	2-eighths	inch wide,	*per dozen*	1	
E 2	1½	—	3-sixteenths	—	—	1	
E 3	1¾	—	2-eighths	—	—	1	6
E 4	2	—	2-eighths	—	—	1	6
E 5	2	—	3-eighths	—	—	1	6
E 6	2½	—	1-half	—	—	2	
E 7	3	—	1-third	—	—	2	
E 8	3	—	1-half	—	—	2	
E 9	3½	—	2-fifths	—	—	2	6
E 10	4	—	1-half	—	—	2	6
E 11	5	—	1-half	—	—	3	
E 12	5	—	5-eighths	—	—	3	
E 13	5½	—	5-eighths	—	—	3	6
E 14	6	—	5-eighths	—	—	3	6
E 15	6	—	3-fourths	—	—	4	
E 16	6	—	7-eighths	—	—	4	
E 17	6½	—	1 inch	—	—	6	

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		s.	d.
E 18	Clark's Conical Test Glass, 1 ounce, with stalk and lip, page 53,		9
E 19	Conical Test Glass, ½ oz., without lip or stalk, page 54,		6
E 20	Conical Test Glass, with stalk and spreading rim, 1 oz.,		5
E 21	Frame for 8 Large Test Tubes with pegs for the tubes, page 51, white wood,	1	6
E 22	Frame for 8 Large Test Tubes, polished black wood, with glazed yellow earthenware pegs,	2	
E 23	Ditto, varnished with copal hard varnish,	2	6
E 24	Frame for 4 Test Tubes, with glazed yellow stone pegs,	1	
E 25	Frame for 6 Test Tubes without pegs, page 50,		6
E 26	Stock Rack for Tubes, consisting of 36 glazed yellow stone pegs, adapted for tubes from 2 inch to 6 inch, fixed on a black wood base, page 284,	3	
	Flint Glass Rod Stirrers, prepared at the ends, page 46,		
E 27	3 inches long, 1-eighth inch wide, *per dozen*	1	
E 28	6 — 1-sixth — —	2	
E 29	9 — 1-fifth — —	3	
	Flint Glass Rods, for Stirrers, in lengths, not prepared,		
E 30	Thick, per yard,		6
E 31	Middle, —		4½
E 32	Thin, —		3
E 33	Dropping Tube, with Bulb, page 57		
E 34	Dropping Tube, Plain, 6 inch, page 58		3
	Test Books, each containing 50 leaves, bound like a banker's cheque book, page 47, *each book*,		1½
E 35	Book of Blue Litmus test papers,		
E 36	Book of Red Litmus,		
E 37	Book of Turmeric,		
E 38	Book of Brazil Wood,		
E 39	Book of Acetate of Lead,		
E 40	Three inch Iron Bar, for metallic precipitation,		1
E 41	Three inch Zinc Bar, — —		1
E 42	Three inch Copper Bar, — —		1
E 43	Fine Copper Wire, for precipitation, per yard,		1
E 44	Zinc Foil, for Ditto, 10 square inches,		
E 45	Test Spoon,—a small spoon with a bowl ¼ inch diameter, for lifting small quantities of powder; the handle serving as a spatula, polished albata,		6
E 46	Berlin Porcelain Spoon, for transvasing acids,	1	
	Bottles for Re-agents, with Ground Stoppers, made according to the shape figured at page 56, with English names of the acids and tests, in black enamel, on a white ground, 3 oz. size, 25 sorts, *each*	2	

E 47	Sulphuric Acid,	E 59	Bicarbonate of Potash,
E 48	Muriatic Acid,	E 60	Iodide of Potassium,
E 49	Nitric Acid,	E 61	Oxalate of Ammonia,
E 50	Potash,	E 62	Carbonate of Ammonia,
E 51	Ammonia,	E 63	Muriate of Ammonia,
E 52	Nitrate of Silver (a black glass bottle),	E 64	Sulphuret of Potassium,
		E 65	Sulphate of Soda,
E 53	Nitrate of Barytes,	E 66	Sulphate of Potash,
E 54	Carbonate of Soda,	E 67	Chromate of Potash,
E 55	Prussiate of Potash,	E 68	Bichromate of Potash,
E 56	Red Prussiate of Potash,	E 69	Protonitrate of Mercury,
E 57	Nitrate of Lead,	E 70	Protochloride of Tin,
E 58	Nitrate of Lime,	E 71	Alcohol.

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		s.	d.
E 72	Set of 52 Bottles for Rose's Tests, 3 and 6 oz., names in Latin in black enamel,	100	
	Bottles for Re-agents, made according to the shape described at page 56, flint glass:—		
E 73	1 ounce, unstoppered,		4
E 74	Ditto, 2 ditto, ditto,		5
E 75	— 3 — —		6
E 76	— 6 — —		9
E 77	— 1 ounce, stoppered,		7
E 78	— 2 — —		8
E 79	— 3 — —		9
E 80	— 6 — —	1	
	Extra Strong Bottles for Re-agents, flint glass:		
E 81	1 ounce, not stoppered,		5
E 82	Ditto, 2 — —		6
E 83	— 2 — stoppered,		9
E 84	— 3 — not stoppered,		8
E 85	— 4 — stoppered,	1	
E 86	— 2 — wide mouth, stoppered,		9
E 87	— 3 — —	1	
E 88	Glass Caps for Acid Bottles, page 56,		4
E 89	Stoneware Caps for Acid Bottles,		2
E 90	Stoneware Bottles for Drugs, with wide mouths, 2 ounce, *per dozen*,	1	
E 91	Ditto, 5 — —	2	
E 92	Corks for the 2 ounce Stone Bottles, —		4
E 93	Ditto 5 — — —		6
E 94	Frame for holding six Acid Bottles, 4 ounce, page 59,		
E 95	Frame for holding eight Test Bottles, 3 ounce,		
E 96	Frame for holding six Test Bottles, 3 ounce,		

F.—PRECIPITATION.

	Beaker Glasses, (bell shaped) for hot liquors, as recommended by Berzelius, thin at sides and bottom, page 62, of flint glass, at the following prices :—		
F 1	3 inches high,		8
F 2	3½ — —		9
F 3	4 — —		10
F 4	5 — —		11
F 5	5½ — —	1	1
F 6	6 — —	1	3
F 7	7 — —	1	6
F 8	8 — —	1	9
F 9	9 — —	2	
F 10	The Set of nine Beaker Glasses, packed in a wooden box,	11	6
	Bohemian Beaker Glasses of hard glass, stronger and better adapted for holding hot liquors than those of flint glass, *all sizes, one-half higher in price.*		
	Cylindrical Jars of flint glass, page 63,		
F 11	2 inches high and 1½ inches wide,		4
F 12	3 — — 1¾ — —		5
F 13	4 — — 2 — —		7
F 14	5 — — 2½ — —		8
F 15	Price of the Set of four cylindrical jars,	2	

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G.—FILTRATION.

		s.	d.
	Glass Filtering Funnels of the form of an equilateral triangle, adapted to fit plain filters, six sizes, page 65 :—		
G 1	No. 1.—1¼ inch diameter,		6
G 2	— 2.—1½ — —		6
G 3	— 3.—2 — —		6
G 4	— 4.—2½ — —		6
G 5	— 5.—3 — —		9
G 6	— 6.—4 — —	1	
G 7	Funnel Holder, consisting of china ring, with rod and foot of white wood, page 66, lower figure,	1	
G 8	Ditto, of polished black wood,	1	3
G 9	Funnel Holder, with wooden ring,		8
G 10	Funnel Holder with Berlin porcelain ring, and polished black wood rod and foot, page 66, 67, 285,	1	6
	Circular Filters, prepared from very pure paper, which contains no soluble matter, gives only one part in 238 of ashes, and filters with rapidity. Sold in packets of 100 filters each, in sizes to suit the foregoing sizes of funnels :—		
G 11	No. 1.—2¼ inch diameter, per 100,		3
G 12	— 2.—2¾ — — —		5
G 13	— 3.—3¼ — — —		7
G 14	— 4.—4½ — — —		8
G 15	— 5.—5½ — — —	1	
G 16	— 6.—7½ — — —	1	4
	Filter Boxes of six sizes, corresponding with the above sizes of filters, each box adapted to contain 100 filters. The boxes are made of pasteboard covered with cloth, and the *number* of the funnel and filter is lettered in gold both on the front and the lid of each box :—		
G 17	No. 1.—for filters No. 1,		3
G 18	— 2.— — — 2,		4
G 19	— 3.— — — 3,		5
G 20	— 4.— — — 4,		6
G 21	— 5.— — — 5,		8
G 22	— 6.— — — 6,	1	
G 23	Price of a Set of six Funnels with best funnel holder, and a set of 6 boxes, each with 100 filters,	12	8
G 24	Price of a Set of Nos. 1, 3 and 5, complete, with common china funnel holder,	5	11
G 25	Ditto, with best Berlin funnel holder	6	5
G 26	Clark's Filtering Ring, one inch diameter, page 72, glass,		
G 27	Ditto, half inch diameter, glass, page 72,		
G 28	— one inch diameter, glazed china,		

H.—EDULCORATION.

H 1	Berzelius's Washing Bottle, with tube, for the edulcoration of precipitates, by a fine but strong current of water, page 80, 6 ounce,	1	
H 2	The glass Tube separately,		2
H 3	Stone Washing Bottle, with a glass tube, 4 ounce		6
H 4	Stone Washing Bottle, 6 oz., with albata tube,	1	

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		s.	d.
H 5	Glass Washing Bottle, 6 oz, with an albata tube, so contrived as to dispense with a connecting cork, and thus obviate the occasional stopping of the tube by fragments of cork, ...	1	6
H 6	The Albata Tube, separately, ...		6
H 7	Washing Bottle, fitted with handle for use with hot water or saline solutions, 6 oz., glass, oval form, with tube, complete, page 81, ...	3	
H 8	Berzelius's Tube for supplying a continual current of pure water to wash a precipitate, page 82, . .	1	3
H 9	The same, made of albata, less fragile, with glass point,		

I.—EVAPORATION AND CRYSTALLISATION.

Evaporating Capsules of Berlin Porcelain, with spreading edge, glazed throughout, pages 85, 86. A few of these basins have no spreading edge, but are provided with a spout. At present, however, they no longer make them at Berlin with a spout.

The depth is one-third of the width.

Nos.	Diameters.	Prices.	Nos.	Diameters.		
I 1	00.—2½ inches, .	s. 6d	I 8	6.— 6 inches, .	2	4
I 2	0.—3¼ — .	8	I 9	7.— 7¼ — .	3	
I 3	1.—3½ — .	10	I 10	8.— 8½ — .	4	
I 4	2.—3¾ — .	1	I 11	9.—10 — .	6	
I 5	3.—4 — .	1 4	I 12	10.—12 — .	9	6
I 6	4.—4½ — .	1 6	I 13	11.—13 — .	10	6
I 7	5.—4¾ — .	1 10	I 14	12.—15½ — .	31	6
I 15	Nest of 4 Berlin Porcelain Capsules, Nos. 00 to 2, .				3	
I 16	Nest of 8 — — — — 00 to 6, .				10	
I 17	Nest of 11 — — — — 00 to 9, .				23	

Evaporating and Crystallising Capsules of salt glazed stoneware, made very thin at the bottom and with spreading edge. Can be heated over hot sand, or over the spirit lamp; useful for crystallising, in consequence of the slight roughness of the surface; also for the evaporation of quantities of saline solutions, which can be carried to dryness, if effected slowly upon one of the lengthening cylinders, C 11.

Depth one-third of the diameter.

	Diameters.	Prices.		Diameter.		
I 18	2½ inches, .	s. 2d.	I 24	5½ inches, .		6
I 19	3 — .	3	I 25	6 — .		6
I 20	3½ — .	3	I 26	7 — .		8
I 21	4 — .	4	I 27	8 — .		9
I 22	4½ — .	4	I 28	9 — .		10
I 23	5 — .	5	I 29	10 — .	1	
I 30	Nest of 12 Stoneware Capsules, Nos. I 18 to I 29, .				6	
I 31	Nest of 6 Stoneware Capsules, — I 18 to I 23,				1	9

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		s.	d.
	Hemispherical Berlin Porcelain Evaporating Basins:— *The depth is half the width.*		
I 32	No. 000.—1 inch diameter,		3
I 33	2.—$1\frac{1}{2}$ —	3	
I 34	3.—$2\frac{1}{2}$ —	3	6
I 35	4.—$3\frac{1}{2}$ — with spout,	5	
I 36	5.—$4\frac{1}{2}$ — —	7	
	Stoneware Evaporating Basins of the hemispherical form, with spreading edge:—		
I 37	No. 1.—4 inch diameter, 2 inch deep,		8
I 38	2.—6 — 3 —	1	
I 39	3.—8 — 4 —	1	4
	Berlin Porcelain Capsule with handle and spout, in one piece, page 13, the sizes adapted to the rings of the lamp furnace:—		
I 40	No. 1.—2 inches diameter,		10
I 41	2.—$2\frac{1}{2}$ — —	1	
I 42	3.—$3\frac{1}{2}$ — —	1	3
I 43	4.—$1\frac{1}{2}$ inch diameter, very light, for weighing the product of an evaporation to dryness,		
	Berlin Porcelain Water Bath, page 89, employed to dry powders, &c.—can be used over the lamp furnace:—		
I 44	No. 00.—$4\frac{1}{2}$ inches diameter,	3	
I 45	0.—5 — —	4	
I 46	1.—$5\frac{1}{2}$ — —	6	6
I 47	**Stoneware Water Bath, same pattern as the Berlin porcelain, $4\frac{1}{2}$ inches diameter, adapted to the lamp furnace.** See C 9,		9
	Berlin Porcelain Cups of thin substance, glazed, for evaporation to dryness, ignition, and weighing:—		
I 48	No. 1.—1 inch wide, $\frac{1}{4}$ inch deep,		
I 49	— 2.—1 — $\frac{1}{2}$ —		
I 50	— 3.—$1\frac{1}{2}$ — $\frac{3}{4}$ —		
	Berlin Porcelain Shallow Plates, for evaporation, intended to replace watch glasses, glazed:—		
I 51	No. 1.—$1\frac{1}{2}$ inch diameter,		
I 52	— 2.—$1\frac{3}{4}$ — —		
I 53	**Platinum Capsule, with spout and handle, pages 13, 14,** 1 inch diameter, one-third inch deep,	7	6
I 54	**Platinum Capsule, $1\frac{1}{2}$ inch wide, three-10ths inch deep,**		
I 55	Ditto, with overhanging edge, $1\frac{1}{2}$ inch diameter,		
I 56	— — — 2 inches —		
I 57	**Platinum Hemispherical Cup, with handle, $\frac{1}{2}$ in. diam.,**	2	
I 58	Ditto, — — — $\frac{3}{4}$ —	5	
I 59	**Platinum Cup, with spreading edge, after Berzelius',** page 14, $\frac{3}{4}$ inch diameter,		
I 60	**Platinum Stirrer, or Spatula, for the small capsules,** round wire, $1\frac{1}{2}$ inch long, one-20th inch thick,	2	
I 61	**Platinum Spatula, flattened wire, one-8th inch broad,** one-20th inch thick, 2 inches long,		
I 62	**Platinum Spatulas of a larger size, charged by weight.**		

K.—IGNITION.

	Berlin Porcelain Crucibles, glazed, conical form, with cover, page 98:—		
K 1	$1\frac{1}{2}$ inch high, by $1\frac{3}{4}$ inch wide,		9
K 2	$1\frac{1}{2}$ inch high, by $2\frac{1}{4}$ inch wide,	1	3

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		s.	d.
	Berlin Porcelain Crucibles, glazed, cylindrical form, with cover, page 286, *a new pattern*:—		
K 3	1¼ inch high, by 1 inch wide, . .		8
K 4	1¾ inch high, by 1½ inch wide, . .		9
	Berlin Porcelain Biscuit Crucibles, for fusing nitrate of silver, &c., with perforated cover to allow the escape of gases, page 99:—		
K 5	2½ inches high, by 1½ inch wide, . .		8
K 6	3¼ inches high, by 2 inches wide, . .		9
	Triangular Hessian Crucibles, without covers, page 99:		
K 7	Small nest of 3 Crucibles, 2 to 3 inches high, .		5
K 8	Small nest of 5 Crucibles, 1 to 4 — .		9
K 9	Large nest of 5 Crucibles, 2 to 5 — .	1	
K 10	Black Lead Crucibles, page 100, 3 inches high, .		4
K 11	Ditto, 3½ inches high, .		8
K 12	Platinum Crucibles, London made, without cover, one-half inch deep, .		
K 13	Ditto, five-eighths — . .		
K 14	— three-fourths— . . } 5s. to	12	
K 15	— seven-eighths— . .		
K 16	— one — . .		
K 17	Platinum Crucible, with cover, 1 inch deep,		
K 18	Ditto, 1½ — } 15s. to	25	
K 19	— 1½ —		
K 20	Berlin Porcelain Cups, which serve the purpose of small crucibles, for igniting precipitates, fusing chloride of silver, &c., glazed, page 98, No. 1.—1 inch diameter,		3
K 21	Ditto, No. 2.—1½ —		3

L.—SUBLIMATION.

	Hard colourless German Glass Tubes, free from lead, for the reduction of arsenical compounds, &c.:—		
L 1	With bulb, same as figure 1, page 104, . .		
L 2	Ditto, same as figure 6, . . .		5
L 3	— same as figure 7, . . .		5
L 4	— same as figure 3, but larger, . .		5
L 5	Straight, same as figure 2.—See E 1 to E 17, .		
L 6	Pointed, same as figure 5, . . .		5
L 7	Open at both ends.—See M 6. . . .		

M.—BLOWPIPE APPARATUS.

M 1	Japanned tin Blowpipe, with moveable brass pipe and brass nozzle, page 110, ...	1	
M 2	Japanned tin Blowpipe Lamp, with cap and supports for the fingers, page 113, ...	1	6
M 3	Rod and Foot for the Lamp, polished black wood, .		6
M 4	A Burner for Gas, costs the same price as the lamp, 1s. 6d.—See C. 30 and page 114,		
M 5	Steel Tongs for dressing the lamp wick, . .	1	
M 6	Glass Tubes, open at both ends, 6 inches long, one-eighth to ¼ inch wide, hard German glass, free from lead, page 121, . . . *per dozen*,	1	6

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		s.	d.
M 7	Tube Vessels of Hard Glass, 6 of 1½ inch long, *for*		6
M 8	Ditto, 6 of 1¾ inch to 2 inches long, ,,		9
M 9	— 6 of 2½ inches long, ,,	1	
M 10	Charcoal, 12 prepared plates, page 123,		3
M 11	Charcoal Borer, to prepare charcoal for supporting assays before the blowpipe, tin plate, page 123,		3
M 12	Charcoal Holder, tin plate, page 123-4, *the pair*,		1
M 13	Platinum Tongs, French pattern, with steel blades and platinum points, best quality, page 124,	7	
M 14	Platinum Foil, in slips of 2 inch by ½ inch, page 125, two slips at 8d.	1	4
M 15	Platinum Wires, 2 inches long, page 125, 3 pieces at 2d.		6
M 16	Brass Wire for the detection of chlorine, page 152,		2
M 17	3 Square Bottles, with plated tops, for borax, soda, and microcosmic salt,	1	
M 18	4 Books of litmus, turmeric, brazil, and lead test paper,		6
M 19	3 Rolls of Tin foil, for reductions, page 175,		1
M 20	Square steel Anvil, page 4,	3	
M 21	Hammer for ditto, page 4,	2	
M 22	Agate Mortar and Pestle,	7	
M 23	Box of Lucifer matches,		1
M 24	Two small 1 inch Porcelain Capsules,		6
M 25	A dozen 2½ inch Tubes, to hold the re-agents enumerated at page 127,	2	
M 26	Albata Spatula and Spoon for mixing powders and lifting fluxes,		6
M 27	Three-square File to cut glass tubes,	1	
M 28	A pair of japanned tin Boxes suitably divided to hold all the preceding articles, as described at page 287,	7	
M 29	Price of the foregoing Blowpipe Apparatus, complete, comprehending M 1 to M 28,	42	
M 30	The same Articles and Boxes, supplied with the following Fluxes and Re-agents in a state of purity,		
	Borax, | Fluorspar,		
	Soda, | Nitrate of Cobalt,		
	Microcosmic Salt, | Oxalate of Nickel,		
	Saltpetre, | Metallic Lead,		
	Bisulphate of Potash, | Bone Ashes,		
	Gypsum, | Silica.		
M 31	The same set of Blowpipe Apparatus as M 29, but with a small glazed Berlin Porcelain Mortar instead of an Agate Mortar, and an inferior pair of Platinum Tongs,	33	
M 32	The same set of Blowpipe Apparatus as M 29, but wanting the following 6 articles:	21	
	Steel Tongs, | Hammer,		
	Platinum Tongs, | Agate mortar,		
	Anvil, | Three square File.		
M 33	The same set of Blowpipe Apparatus as M 29, with the substitution of a lamp with a screw for travelling	44	
M 34	Blowpipe Lamp with a screw for travelling,	3	6
M 35	Berlin Porcelain Cup, one-third inch diameter, with handle and cover, for the ignition of decrepitating substances,		
M 36	Berlin Porcelain Bottle for solution of cobalt,		

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N.—DISTILLATON.

		s.	d.
	Hard German Glass Retorts:—		
N 1	½ oz. capacity, made from tubes for delicate experiments,		10
N 2	Ditto, 2 oz.	1	6
N 3	— 4 oz.	1	9
	Hard German Glass Retorts, stoppered:—		
N 4	1 oz. capacity,	1	6
N 5	Ditto, 2 oz.	2	6
N 6	— 4 oz.	3	
	Flint Glass Retorts, plain,		
N 7	2 oz. capacity,		6
N 8	Ditto, 4 oz.		9
N 9	— 8 oz.	1	
N 10	— 12 oz.	1	6
	Flint Glass Retorts, stoppered.		
N 11	2 oz. capacity,	1	2
N 12	Ditto, 4 oz.	1	6
N 13	Ditto, 8 oz.	1	9
	Berlin Porcelain Retorts, glazed within, biscuit without:		
N 14	Unstoppered, No. 1.— 7 inches long,	3	
N 15	— — 2.— 9 —	4	6
N 16	— — 3.—16 —	7	6
N 17	Stoppered, — 1.— 7 —	4	
N 18	— — 2.— 9 —	6	
N 19	— — 3.—16 —	10	6
N 20	Stoneware Still, for the preparation of pure water, muriatic acid and similar operations: consists of several portions of the lamp furnace, page 289, 6 pieces,	3	2
N 21	Tin plate Still, for the distillation of water, alcohol, or volatile oils, one pint capacity, see page 290,	3	
N 22	Flint Glass Receiver, 2 oz. capacity, with long neck,		6
N 23	Ditto, (same as B 7), 8 oz. capacity,		8
N 24	German glass receiver, or intermediate vessel, with two necks, *g*, page 229	2	
	CONDENSERS:—		
N 25	Condenser, page 201, (lower figure), tin plate tube, 17 by 2 inches, with leaden pipes for changing the water, japanned inside and outside, without central tube,	4	
N 26	Ditto, fitted with a glazed stoneware tube, 25 inches by ¾ inch, page 202,	5	6
N 27	Ditto, fitted with a glass tube, slightly conical, 25 inch long, the upper mouth wide and bordered, the lower end contracted,	8	
N 28	Condenser, small size, page 199, 12 inch japanned tin plate tube, without glass tube,	1	6
N 29	Ditto, fitted with 18 inch glass tube,	2	6
N 30	Condenser, 12 inch brass tube, 1 inch wide, without glass tube,	1	6
N 31	Condenser, 12 inch stoneware tube, 1¼ inch wide, fitted with an 18 inch glazed stoneware tube, ½ inch wide,		
	The glazed stoneware tubes are much stronger than the glass tubes, and very well adapted for distilling water, and for other common operations; but being slightly rough, they cannot be cleaned so perfectly as the glass tubes, and are consequently not so fit for analytical operations.		

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		s.	d.
N 32	Stone Bottle, with spigot hole at the side for supplying a current of water, 1 quart,	1	
N 33	Ditto, 1 gallon,	2	
N 34	Brass Stop Cock for either of these bottles,	2	

O.—APPARATUS FOR GASES.

a. For Preparing Gases.

O 1	Gas Bottle, oval form, with turned lip, long funnel, two bent tubes, and caoutchouc connector, page 209,	3	6
O 2	The same Gas Bottle, not fitted up,	1	4
O 3	Clark's Gas Bottle, for testing with sulphuretted hydrogen gas, and for preparing hydrogen, carbonic acid, and other gases, page 209,	3	
O 4	Woulfe's Bottle, with 2 necks, salt glazed stoneware, *pint*, page 211,	1	
O 5	The same, fitted with diagonal tube for the preparation of hydrogen gas, carbonic acid gas, sulphuretted hydrogen gas, &c.,	1	6
O 6	Stoneware Gas Bottle, with bent neck, page 211, 10 oz., without funnel, for the same uses as Clark's bottle,	1	
O 7	Hard Glass Tube Retort, fitted to a delivering tube, for oxygen gas, page 206,		8
O 8	Ditto, larger size, a six inch retort,	1	
O 9	Gas Delivering Tube, narrow, page 208, *the yard*,		6
O 10	Ditto, wider, *the yard*,		8
O 11	Bent Gas Delivering Tubes, page 208, each 3d. to		6

b. For Collecting and Examining Gases.

O 12	Stoneware Gas Holder, 1½ gallon, with funnel, flexible pipe, and coupling screws, complete, page 214,	8	6
O 13	Ditto, 2 gallons, complete,	10	
O 14	Stoneware Pneumatic Trough, circular, 11 inches by 5 inches, with bee hive shelf, for supporting jars, and conveying the gas into them, page 214, 215,	2	
O 15	The Bee-hive Shelf, alone, page 215,		6
O 16	Three stoneware Trays for removing the jars from the trough when filled with gas, page 213, *the set*,		4½
O 17	Set of four Cylindrical Gas Jars, see F 11 to F 14,	2	
O 18	Open Deflagrating Jar, for exhibiting the combustion of phosphorus in oxygen gas, &c.,	1	
O 19	Iron Deflagrating Spoon,		6
O 20	Complete Set of Apparatus for collecting and experimenting upon gases, including O 12, 14, 16 to 19,	14	4½
O 21	Japanned tin plate Pneumatic Trough, upon an improved construction, for jars of 60 cubical inches, with sliding shelf and tray, page 217,	4	
O 22	Pneumatic Trough for Tubes, in a single piece of stone, intended for either water or mercury, and requiring less than 4 lbs. of the latter to work it. Takes in tubes 6 inches long, ½ inch internal diameter, with a space for passing solutions, by means of a smaller tube, into gases over mercury. Has a bee-hive shelf for supporting the tubes while filling with gas, page 218,	1	6

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		s.	d.
O 23	Berlin Porcelain Trays, for lifting tubes filled with gases from the trough O 22, 1 inch diameter, *each*		1½
O 24	Berlin Porcelain Mercurial Trough, in a single piece, page 217,	10	
O 25	Berlin Porcelain Mercury Pot, with cover and spout in one piece, 6 inches high, 3 inches wide, with name in black enamel,	4	
	Berlin Porcelain Tubes, glazed, for containing substances subjected to gases at a high temperature, page 227:—		
O 26	Half inch wide, 8 inches long,	2	6
O 27	— 13 —	4	
O 28	— 26 —	6	6
O 29	1½ inch wide, 15 —	8	6
O 30	Porcelain Trays to contain substances placed in such tubes, page 227, 3 or 4 inches long, *each*		8
O 31	Hard Glass Tubes for the reduction of metals by ignition in gases, page 226, 15 inches long, with one bulb,	1	3
O 32	Ditto, with two bulbs,	1	6
O 33	Tube to contain fused chloride of calcium for Drying Gases, page 224, 9 inches by ¾ inch,		9
O 34	Bell glass, with ground stopper, 6 inch by 2 inch,	2	6
O 35	Ditto, 7 inch by 3 inch,	4	
O 36	Cooper's Mercurial Receiver, 12 inch, page 219,		
O 37	Ditto, graduated into cubical inches and parts,	6	6

P.—WEIGHING AND MEASURING.

P 1	Apothecaries' Scales, with a set of weights from ½ grain to 2 drams, in a box,	4	
P 2	Ditto, superior, with polished box,		
P 3	Glass Measure for liquids, 1 ounce, cylindr., graduated,	1	
P 4	Ditto, — — conical, —	2	
P 5	Graduated Glass Measure, 4 ounce,		
P 6	Iron Beam with horn scales, (German), 2s. 6d. to	3	6
P 7	Cubic Inch Bottle, for specific gravities, long neck,	1	6
P 8	Ditto, with perforated stopper,		

Q.—GLASS BLOWING.

GLASS TUBES, in lengths of three feet.
The Nos. express the sizes described on page 245.

	Hard German Glass:—		
Q 1	Nos. 1, 2, 3 and 4, per yard,		6
Q 2	— 5, —		8
Q 3	— 6, —		10
Q 4	— 7 to 12, per lb.,	5	
	Soft Flint Glass Tubes:—		
Q 5	Nos. 3, 4 and 5, per yard,		6
Q 6	— 6, —		8
Q 7	— 7 to 12, per lb.,	4	
Q 8	Lancashire File, three square, for cutting glass,	1	
Q 9	Cast steel Knife for cutting glass,		
Q 10	Pastile Glass Cutters, 6 inch, page 249,		2

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		s.	d.
Q 11	Water pressure Blowpipe, with stoneware double cistern in one piece, and bellows to supply air; fitted on a frame with treadle, spring, air pipes, and nozzles, as described at page 239, but without table,		
Q 12	The double Stoneware Cistern, apart,		
Q 13	Glass Blower's Lamp, complete, tin plate,		
Q 14	Ditto, superior, after Danger's pattern, with hood to condense the smoke, tin plate,		

R.—CORK BORING.

R 1	Three inch Round File, without handle,		9
R 2	Six inch Round File, without handle,	1	
R 3	Six inch Flat File, without handle,		6
R 4	Danger's Cork Borer, steel tube, with wooden handle, 1-fifth to 1-third inch bore, page 266, each,	1	3
R 5	Set of 6 Brass Tube Cork Borers, one-6th to ½ inch diameter, 4 inches long, page 268,	1	
R 6	Set of 12 Brass Tube Cork Borers, 6 inches long, and 2, 3, 4, 5, 6, 7, 8, 10, 12, 14, 16, and 20 sixteenths of an inch diameter, page 269,	3	
R 7	Set of 7 Brass Tube Cork Borers, 6 inches long, and 2, 3, 4, 5, 6, 7, and 8 sixteenths of an inch in diameter,	1	6

S.—MISCELLANEOUS APPARATUS.

S 1	Sheet Caoutchouc, for making Elastic Tubes, page 269, 25 square inches,		6
S 2	Ditto, 100 square inches,	1	6
S 3	Caoutchouc Connectors, prepared for use, 1½ inch long 1-third inch wide,		
S 4	Ditto, 2 inches by ½ inch,		
S 5	Hydrogen Gas Lamp, for the instantaneous production of light by the action of hydrogen gas upon platinum, *stoneware*,		
S 6	Lucifer Matches, box of one hundred,		2
S 7	Siliceous Varnish, to render paper incombustible, page 264, sealed bottle of 10 oz.	3	
S 8	Shears for cutting sheet metals, *per pair*	2	
S 9	Steel Tongs for lifting weights, trimming lamps, &c.	1	
S 10	Ditto, with a spoon-shaped handle, for lifting fluxes,	1	6
S 11	Pyrope, Bohemian garnets, for counterpoising, cleaning bottles, &c., per ounce,		3
S 12	Magnets, horse shoe form, with keeper,	1	
S 13	Berlin Porcelain Medicine Spoon, by means of which invalids with one hand at liberty can assist themselves,	2	6
S 14	Young's improved Voltaic Battery for the decomposition of water and of saline solutions, for the combustion of metals, and the production of electro-magnetic phenomena, in a stoneware trough,	20	
S 15	Caoutchouc Flexible Tube, 1-third inch wide, per foot,		
S 16	— — 1-half — —		
S 17	— — One — —		

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ESTIMATES
FOR
SETS OF CHEMICAL APPARATUS,
OF VARIOUS EXTENT,
SELECTED FROM THE FOREGOING CATALOGUE.

We are induced to offer the following Estimates in consequence of the numerous applications which have been made to us to learn the *cost of a Set of our Apparatus.*

The Estimates present what appear to us to be articles of most general use. We wish it, however, to be understood, that we are ready, in every case, to vary the selection according to the instructions which we may receive from the purchaser, so that no person need take duplicates of apparatus already in his possession, nor be deprived of articles that he may wish to have, although not quoted in the Estimates. We therefore take the liberty to request that every order for one of the following Sets of Apparatus may be accompanied by a note of what the purchaser wishes to have omitted, or of what he would like to have in addition to the articles embraced in the Estimate.

		s.	d.
	Set I.—£1 1s. For Small Preparations, Elementary Testing, &c.		
A 8	Berlin Porcelain Pestle and Mortar,	1	
B 2, 6	Two Glass Solution Flasks,	1	2
C 21	Lamp Furnace,	3	
D 2	Tube Holder,	1	
E 1, 2, 4, 8, 11, 14	Test Tubes, two of each,	2	2
E 20	Two Conical Test Glasses,		10
E 25	Small Tube Frame,		6
E 27, 28, 29	Three Glass Stirrers,		6
E 35, 37	Two Test Books,		3
E 40, 41, 42	Three Precipitating Bars,		3
E 45	Test Spoon and Spatula,		6
F 15	Set of 4 Cylindrical Jars,	2	
G 3	Filtering Funnel,		6
G 9	Funnel Holder,		8
G 13	100 Circular Filters,		7
H 3	Stone Washing Bottle,		6
I 1	Porcelain Capsule,		6
I 19, 21, 23	Three Stoneware Capsules,	1	
K 3	Berlin Porcelain Crucible,		8
K 21	Berlin Porcelain Cup,		3
M 1	Japanned Blowpipe,	1	
N 7	Flint Glass Retort,		6
O 6	Stoneware Gas Bottle,	1	
O 9	Three feet of Gas Delivering Tube,		6
R 5	Small Cork Borer,		2
	Set II.—£1 1s. For Experimenting upon Gases.		
N 8	Glass Retort, 4 ounce,		9
O 1	Gas Bottle fitted for use,	3	6

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		s.	d.
O 6	Stoneware Gas Bottle, with bent neck,	1	
O 8	Oxygen Gas Retort, with tube,	1	
O 9	Gas Delivering Tube, 3 feet,		6
O 20	Apparatus for Collecting Gases,	14	4½

SET III.—£2 2s.

M 29	Complete set of APPARATUS for ANALYSIS by the BLOWPIPE,	42	

SET IV.—£12 12s.

Containing a complete set of APPARATUS for ELEMENTARY EXPERIMENTS on GASES; for DEMONSTRATING the PROPERTIES of the Principal CHEMICAL SUBSTANCES; for LIQUID TESTING; and for BLOWPIPE ANALYSIS.

A 8, 9	Two Berlin Porcelain Mortars,	3	6
B 1 to 7	Seven Solution Flasks, assorted,	4	4
B 14,	Two Boiling Tubes,		8
B 18, 19	Two Porcelain Digesters,	2	
C 19	Lamp Furnace, 18 articles,	8	6
C 22	Large Spirit Lamp,	12	
C 32	Gas Light Fittings,	13	6
D 1	Triangle Retort Stand,	1	
D 2	Metallic Tube Holder,	1	
D 7	Set of six Blocks of Wood,	1	6
D 14	Universal Support, four branches,	14	
D 26	Set of Supports for the Large Lamp, &c.,	6	
E 1—17	Assortment of Test Tubes, 3 to 6 inches,	8	6
E 18	Eight Clark's Test Glasses, with lip,	6	
E 20	Eight Conical Test Glasses, with spreading edge,	3	4
E 22	Tube Rack, 8 holes, with stoneware pegs,	2	
E 26	Stock Tube Rack, 36 pegs,	3	
E 27	Twelve Glass Stirrers, 3 inch,	1	
E 28, 29	Three Stirrers, two each, 6 and 9 inch,	1	3
E 34	Two Dropping Tubes,		6
E 35—39	Twelve Test Books assorted,	1	6
E 40—42	Six Precipitating Bars,		6
E 46	Porcelain Spoon for Acids,	1	
F 10	Set of nine Beaker Glasses in a box,	11	6
G 23	Set of Filtering Apparatus, six sizes,	12	8
H 1	Berzelius's Washing Bottle,	1	
H 7	Ditto, for hot water, with handle,	3	
I 16	Eight Berlin Porcelain Capsules, 2¾ to 6 inches,	10	
I 30	Twelve Stoneware Capsules, 2½ to 10 inches,	6	
I 38	Stoneware Deep Basin, 6 inch,	1	
I 40—42	Three Berlin Capsules, with handle	3	1
K 1 to 4	Four Porcelain Crucibles, assorted,	3	5
K 8	Nest of five Hessian Crucibles,		9
K 20, 21	Two Porcelain Cups,		6
M 29	Blowpipe Apparatus,	42	
N 7, 12	Two Flint Glass Retorts,	2	
N 1	Small Hard Glass Retort,		10
N 27	Condenser, with glass tube,	8	
N 29	Condenser for small operations,	2	6
N 32, 34	Quart Stone Bottle, with stop cock, for water,	3	
O 1	Gas Bottle, fitted with tubes,	3	6
O 2	Ditto, not fitted,	1	4

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		s.	d.
O 3	Clark's Gas Bottle,	3	
O 4	Woulfe's Bottle, stoneware,	1	
O 6	Stoneware Gas Bottle, bent neck,	1	
O 8	Tube Retort for oxygen gas,	1	
O 9	Six feet of Gas Delivering Tube,	1	
O 20	Gas Apparatus, complete,	14	4½
O 22	Stone Trough for mercury,	1	6
O 23	Two Berlin Trays, for Gas tubes,		3
O 31	Tube for the Reduction of metals,	1	3
O 33	Desiccating Tube,		9
O 34	Bell glass, with ground stopper,	2	6
P 1	Apothecaries' Scales and Weights,	4	
P 3	Graduated Measure, 1 ounce,	1	
R 6	Set of twelve Brass Cork Borers,	3	
R 1, 2, 3	Set of Files,	2	3
S 2	Sheet of Caoutchouc for connectors,	1	6

Set V. £10 10s.

The same as Set IV., with the omission of the Blowpipe Apparatus, M 29.

Set VI.—£5 5s.

A 8, 9	Two Berlin Porcelain Mortars,	3	6
B 1, 3, 6, 8	Four Solution Flasks,	2	5
B 14	Boiling Tube,		4
B 19	Porcelain Digester,	1	
C 19	Lamp Furnace, complete,	8	6
C 22	Large Spirit Lamp,	12	
D 1	Triangle Retort Stand,	1	
D 2	Metallic Tube Holder,	1	
D 9, 28	Holder for the Spirit Lamp,	4	6
D 12	Sefstroem's Press Holder,	3	6
D 21	Pan for working upon,	1	6
E 1, 3, 8	Eighteen Tubes for Sublimation and Testing,	2	3
E 14	Eight ditto, large,	2	4
E 20	Six Conical Test Glasses,	2	6
E 22	Frame for eight Test Tubes,	2	
E 27	Six Glass Stirrers, 3 inch,		6
E 28, 29	Two Stirrers, each 6 and 9 inch,		10
E 34	Dropping Tube, plain,		3
E 35 to 39	Six Test Books assorted,		9
E 40 to 42	Three Precipitating Bars,		3
E 45	Test Spoon and Spatula,		6
F 1 to 6	Six Beaker Glasses,	5	6
G 25	Small set of Filtering Apparatus,	6	5
H 1	Berzelius's Washing Bottle,	1	
I 15	Nest of four Porcelain Capsules,	3	
I 31	Nest of six Stoneware Capsules,	1	9
I 37	Deep Stoneware Basin,		8
K 1, 3	Two Porcelain Crucibles,	1	5
K 20, 21	Two Porcelain Cups,		6
N 7, 8	Two Plain Glass Retorts,	1	3
N 26	Condenser and Stoneware Tube,	5	6
O 2	Gas Bottle, glass, oval,	1	4
O 4	Woulfe's Bottle, stoneware, 2 necks,	1	
O 6	Stoneware Gas Bottle, bent neck,	1	
O 8	Hard Glass Retort for Oxygen Gas,	1	

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		s.	d.
O 9	Gas Delivering Tube, 6 feet,	1	
O 20	Stoneware Gas Apparatus,	14	4½
O 22	Pneumatic Trough for Tubes,	1	6
O 23	Small Berlin Tray for Tubes,		1½
R 7	Seven Brass Cork Borers,	1	6
S 1	Twenty-five square inches of Caoutchouc,		6
R 1 to 3	Set of Files for Cork and Cork Borers,	2	3
Q 8	Triangular File to cut glass,	1	

Set VII.—£3 3s.

This set includes a Selection from the Apparatus for Blowpipe Analysis and for Experiments upon Gases.

A 8	Small Porcelain Mortar,	1	
B 2, 6, 7	Three Solution Flasks,	1	10
C 19	Lamp Furnace, complete,	8	6
D 1	Triangle Retort Holder,	1	
D 2	Metallic Tube Holder,	1	
E 1 to 17	Three Tubes, each 1d., 1½d., 2d., 2½d., 3d., 3½d,		4
E 21	Frame for eight Test Tubes,	1	6
E 29	Three Conical Glasses on foot,	1	3
E 27	Three Stirrers, 3 inch,		3
E 28, 29	One Stirrer, each 6 and 9 inch,		5
E 34	One Dropping Tube, plain,		3
E 35—39	Six Test Books assorted,		9
E 40—42	Three Precipitating Metals,		3
E 45	Test Spoon and Spatula,		6
F 1 to 4	Nest of four Beaker Glasses,	3	2
F 15	Nest of four Glass Cylinders,	2	
G 24	Filtering Apparatus, 3 sizes,	5	11
H 3	Stone Washing Bottle,		6
I 15	Nest of four Porcelain Basins,	3	
I 31	Nest of six Stoneware Basins,	1	9
K 1	Berlin Porcelain Crucible,		9
K 20, 21	Two Berlin Porcelain Cups,		6
M 1	Japanned Blowpipe,	1	
M 2, 3	Blowpipe Lamp and Support,	2	
M 6	Six Hard Glass open Tubes,		9
M 11, 12	Charcoal Borer and Holder,		4
M 14, 15	Platinum Foil and Wire,		10
M 16, 19	Brass Wire and Tin Foil,		3
M 24	Small Porcelain Capsule, 1 inch,		3
N 7	Glass Retort, 2 ounce,		6
N 29	Small Condenser and Tube,	2	6
O 4	Woulfe's Bottle, stoneware,	1	
O 6	Stoneware Gas Bottle, with bent neck,	1	
O 7	Oxygen Gas Retort, small size,		8
O 9	Gas Delivering Tube, 3 feet,		6
O 14	Stoneware Pneumatic Trough,	2	
O 16	Two Stoneware Trays,		3
O 18	Open Deflagrating Jar,	1	
O 19	Iron Deflagrating Spoon,		6
P 1	Apothecaries Scales and Weights,	4	
P 3	Graduated Ounce Measure,	1	
Q 8	Triangular File to cut Glass,	1	
R 1, 3, 7	Round and Flat File, and set of four Cork Borers,	2	3

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(Soda) cryst.
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Muriate.
Nitrate.
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Sulphuret (native).
Barium, Chloride.
Barytes, Acetate.
Carbonate, precipitated.
Caustic, cryst.
Nitrate.
Sulphate (native).
Bismuth, Metallic.
Subnitrate.
Boracic Acid.
Borate of Soda (Borax).
Bromide of Potassium.
Sodium.
Bromine.
Cadmium, Carbonate.
Metallic.
Sulphuret.
Sulphate.
Calcium, Chloride, cryst.
Fluoride.
Chlorate of Potash.
Chloride of Lime.
Chromate of Potash, yellow.
red.
Cobalt, Black Oxide.
Copper, Black Oxide.
Nitrate.
Sulphate.
Formate of Soda.
Gall Nuts.
Gold Leaf.
Indigo.
Iodide of Potassium.
Iodine.
Iron, Sulphuret.
Sulphate.
Persulphate.
Lead, Acetate.
Carbonate.
Nitrate.
Lime, Carbonate. Nitrate.
Caustic.
Litmus.
Magnesia, Carbonate. Sulphate.
Manganese, Peroxide.
Mercury, Cyanide.
Chloride (calomel).
Metallic.
Nitrate.
Perchloride (cor. sub.).
Red Oxide, precip.
Microcosmic Salt.
Nickel, Metallic.
Oxalate of Ammonia.
Oxalic Acid.
Palladium, Metallic.
Platinum, spongy.
Phosphate of Soda.
Phosphoric Acid, fused.
Phosphorus.
Potash, Bicarbonate. Bisulphate, crystallized. Ditto, pulverised. Carbonate purified. Do. very pure. Caustic, in sticks. Do. very pure. Nitrate. Sulphate.
Potassium, Metallic.
Sulphocyanide.
Sulphuret.
Prussiate of Potash, yellow.
red.
Silicate of Potash (basic).
Silver, Nitrate, cryst.
Soda, Bicarbonate.
Carbonate.
Sulphate.
Sodium, Metallic.
Starch.
Strontian, Carbonate. Nitrate.
Strontium, Chloride.
Succinic Acid.
Succinate of Ammonia.
Succinate of Soda.
Tartaric Acid.
Tin, Protochloride, cryst.
Turmeric.
Uranium, Yellow Oxide.
Zinc, Metallic, granulated.
Sulphate. White Oxide.

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